GTE-ERS
TECHNICAL LIBRARY
00927

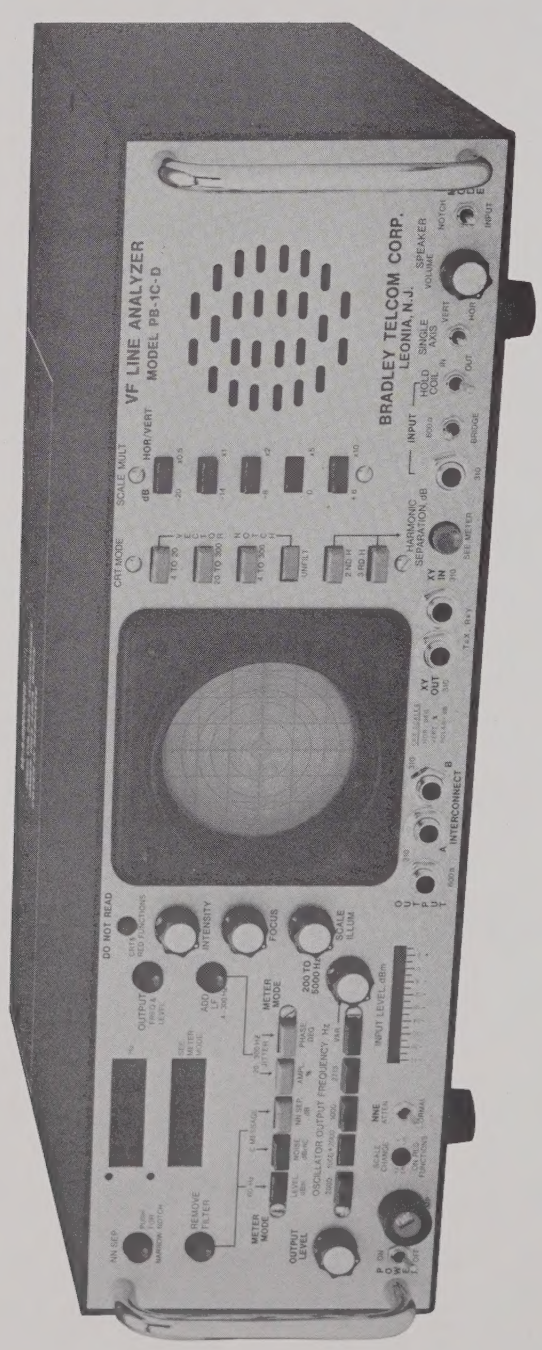
BRADLEY TELCOM CORP.

PC-1C-D

INSTRUCTION MANUAL
FOR
MODEL PB-1C-D
VF LINE ANALYZER

BRADLEY TELCOM CORP.
117 Fort Lee Road
Leonia, New Jersey 07605

Copyright © 1983


VF LINE ANALYZER
MODEL PB-1C-D
BRADLEY TELCOM CORP.
LEONIA, N.J.
DO NOT READ
INTENSITY
FOCUS
SCALE ILLUM
INTERCONNECT
OUTPUT LEVEL
REMOVE FILTER
METER MODE
OSCILLATOR OUTPUT FREQUENCY Hz
200 TO 5000 Hz
INPUT LEVEL
SPEAKER VOLUME
HARMONIC SEPARATION dB
XY IN
XY OUT
SCALE MULT
CRT MODE
HOR/VERT
SINGLE AXIS
HOLD COIL
NOTCH
BRIDGE

WARRANTY

All Bradley Telcom Corp. products are warranted to the original purchaser or user against defects in material and workmanship for a period of one year. Bradley Telcom Corp. will repair or replace products which prove to be defective during the warranty period. This does not apply to items that have a limited life expectancy, e.g., lamps and fuses, nor to CRT burn spots since these are the result of improper operation. Upon authorization by Bradley Telcom Corp., the equipment may be returned to the factory prepaid for repair (see Procedure for Repair and Return). Upon completion of repair, the equipment will be returned at Bradley Telcom Corp. expense. If, upon examination of the defective items, it is evident that failure was not due to defective workmanship or material, Bradley Telcom Corp. will request a purchase order covering the cost of replacement or repair and will bill for transportation charges.

Bradley Telcom Corp. reserves the right to make changes in the design or construction of its products at any time without incurring any obligation to make changes on units previously purchased.

Bradley Telcom Corp. does not warrant the merchantability or the fitness for a particular purpose of its products. No other warranty other than contained herein is expressed or implied. Bradley Telcom Corp. is not liable for consequential damages nor for damage during shipment back to the factory. Returns must have prior factory approval.

We have experienced shipping damage to returned units due to improper packing. Insurance with the carrier does not solve this problem since a unit which has freedom of movement inside a carton can be damaged without apparent external damage to the carton and, therefore, not covered by the carrier insurance. If there is any doubt about packing capability, upon request, material will be shipped from the factory for this purpose.

PROCEDURE FOR REPAIR AND RETURN

Call Repair Department (201) 461-5903 and request a Return Authorization. Units will not be accepted unless they have an RA number on the shipping label. The person in the Repair Department will advise as to necessity of purchase order, terms, etc. Return the product, well packed and prepaid, to Bradley Telcom Corp. at 117 Fort Lee Road, Leonia, New Jersey 07605, attention Repair and Return. Enclose an explanation of the malfunction, your company's name and address, and the name and telephone number of a person to contact for further information.

Procedures and equipment equivalent to those used during the product's original qualification tests will be used. Standard products will be repaired and updated to the latest revision level practicable within that product's issue level. Revision updating requiring printed circuit board redesign or structural redesign will not be performed.

For any product under warranty that, when calibrated using procedures given in its Instruction Manual, satisfies its original specifications there is a retest charge.

TECHNICAL SUPPORT

Technical support is provided by the local sales representative for Bradley Telcom Corp. or by the factory (201-461-5903). Service and repair is provided by the factory. In the event of a problem with this instrument call 201-461-5903 and the Service Desk will issue a return authorization number and will give instructions to expedite handling your equipment.

TABLE OF CONTENTS

Par.		Page
	WARRANTY, PROCEDURE FOR REPAIR AND RETURN, TECHNICAL SUPPORT	iii
0-1.	**OPERATIONAL & CAUTION NOTES**	0-1
	OPERATING NOTE	0-3
	SECTION I GENERAL INFORMATION	
1-1.	INTRODUCTION	1-1
1-2.	Scope of Manual	1-1
1-3.	PB-1C-D VF Line Analyzer	1-1
1-4.	NOTES ON THE PB-1C-D DISPLAYS	1-1
1-6.	Digital Displays	1-1
1-7.	Phasor-Domain CRT Display	1-1
1-8.	Facility-clearing Capability	1-1
1-11.	FEATURES OF THE PB-1C-D	1-2
1-12.	CAPABILITIES OF THE PB-1C-D	1-2
1-13.	Phasor-Domain CRT Display	1-2
1-14.	Digital Multi-Mode Meter	1-3
1-15.	Digital Frequency Meter	1-3
1-16.	Fast-Reading Level Meter	1-3
1-17.	Loudspeaker	1-3
1-18.	NOTES ON MEASUREMENTS OF IMPAIRMENTS	1-3
1-19.	Properties Versus Impairments	1-3
1-20.	Definitions of Impairments	1-3
1-21.	Notched-Noise Measurements of Impairments	1-4
1-22.	Phasor-Domain Analysis of Notched Noise	1-4
1-23.	SIMPLIFIED BLOCK DIAGRAM OF PB-1C-D PHASOR-DOMAIN CIRCUITS	1-5
	SECTION II DESCRIPTION OF PB-1C-D ANALYZER	
2-1.	EXTERNAL DESCRIPTION	2-1
2-3.	Front of Instrument	2-1
2-5.	Side and Rear of Instrument	2-1
2-7.	FUNCTIONS OF CONTROLS, DISPLAYS, AND INDICATORS	2-1
2-8.	POWER Switch and Fuse	2-1
2-9.	INPUT Jack, Switches, and Display	2-1
2-10.	Digital Frequency Meter and Controls	2-2
2-11.	Digital Multi-Mode Meter and Controls	2-2
2-12.	Oscillator Controls, Displays, and Jack	2-5
2-13.	CRT, GRATICULE, CONTROLS, AND INDICATOR	2-5
2-14.	CRT MODE Pushbuttons	2-6
2-15.	SCALE MULT Pushbuttons	2-6
2-16.	SINGLE AXIS Switch	2-6
2-17.	XY IN Jack	2-8
2-18.	XY OUT Jack	2-8
2-19.	HARMONIC SEPARATION Pushbutton	2-8
2-20.	INTERCONNECT A and B Jacks	2-8
2-21.	Rear Connector	2-8
2-22.	LOUDSPEAKER AND CONTROLS	2-8
2-23.	NNE Switch and SCALE CHANGE ON RED FUNCTIONS Indicator	2-8
2-24.	Rack Adapter Kit	2-9

Par.		Page
	SECTION III THEORY OF OPERATION	
3-1.	GENERAL	3-1
3-2.	OSCILLATOR CIRCUIT	3-1
3-3.	INPUT CIRCUIT	3-3
3-4.	PHASOR-DOMAIN CIRCUITS	3-3
3-5.	Notch Phase-Lock Loop, NPLL	3-3
3-6.	Automatic Gain Control (AGC) Loop	3-3
3-7.	Display Phase-Lock Loop, DPLL	3-5
3-8.	Valid Signal Detector and DO NOT READ Indicator	3-5
3-9.	NNE Switch	3-5
3-10.	Cosine And Sine Multipliers	3-5
3-11.	CRT Display Circuits	3-6
3-12.	SPEAKER CIRCUIT	3-7
3-13.	METER CIRCUITS	3-7
3-14.	FREQUENCY METER	3-7
3-15.	FAST INPUT LEVEL METER	3-7
3-16.	MULTI-MODE METER	3-9
3-17.	dB Card	3-9
3-18.	LEVEL Mode	3-9
3-19.	NOISE Mode	3-11
3-20.	NN SEP Mode	3-11
3-21.	AMPL. JITTER Mode	3-11
3-22.	PHASE JITTER Mode	3-11
3-23.	2ND HARMONIC SEPARATION Mode	3-11
3-24.	3RD HARMONIC SEPARATION Mode	3-13
	SECTION IV OPERATION AND DATA INTERPRETATION	
4-1.	GENERAL	4-1
4-3.	OSCILLATOR OPERATION	4-2
4-4.	FREQUENCY METER OPERATION	4-2
4-5.	MULTI-MODE METER OPERATION	4-2
4-6.	USE OF FAST INPUT-LEVEL METER	4-3
4-7.	SPEAKER OPERATION	4-3
4-8.	PHASOR-DOMAIN CRT OPERATION	4-4
4-9.	VECTOR NOTCH Measurements	4-4
4-10.	Distortion Measurements In UNFILT VECTOR NOTCH MODE	4-4
4-11.	Distortion Measurements In 2ND H and 3RD H MODES	4-5
4-12.	MEASUREMENT TECHNIQUES	4-5
4-13.	Notched Noise Measurements	4-5
4-14.	Impulse Noise Measurements	4-5
4-15.	Single-Frequency Interference (SFI) Measurements	4-5
4-16.	Phase-Jitter Measurements	4-5
4-17.	Phase-Hit Measurements	4-6

Par.		Page
4-18.	Gain Hit/Dropout Measurements	4-6
4-19.	Harmonic Measurements	4-6
4-20.	Frequency Shift (Translation)	4-6
4-21.	INTERPRETATION OF CRT DISPLAYS	4-7
4-22.	General	4-7
4-23.	Analysis of Impairments In VECTOR NOTCH MODE	4-7
4-24.	Distortion Analysis, UNFILTered VECTOR NOTCH MODE	4-8
4-25.	Harmonic Distortion Analysis, 2ND H & 3RD H MODES	4-8
4-26.	Phase-Intercept Distortion	4-9
4-27.	PB-1C-D with P/AR Adapter	4-9
4-29.	SELF-CHECK OF PB-1C-D	4-9
	SECTION V ALIGNMENT PROCEDURES	
5-1.	GENERAL	5-1
5-2.	EQUIPMENT REQUIRED FOR ALIGNMENT	5-1
5-3.	NOTES ON USE OF SFI FOR ALIGNMENT	5-1
5-4.	REMOVAL AND REPLACEMENT OF COVER	5-1
5-5.	LOCATIONS OF ADJUSTMENTS	5-2
5-6.	FREQUENCY METER CHECK	5-2
5-7.	FAST INPUT LEVEL METER ADJUSTMENTS	5-2
5-8.	OSCILLATOR FREQUENCY ADJUSTMENTS	5-6
5-9.	MULT-MODE METER ADJUSTMENTS	5-6
5-10.	LEVEL Mode Adjustments	5-6
5-11.	NOISE Mode Adjustments	5-6
5-12.	CRT, TILT, CENTERING, AND ASTIGMATISM ADJUSTMENTS	5-7
5-13.	VECTOR NOTCH CHECKS AND ADJUSTMENTS	5-7
5-14.	CRT DPLL Adjustments	5-8
5-15.	NN SEP Mode Adjustments	5-9
5-16.	AMPL. JITTER Mode Adjustments	5-9
5-17.	PHASE JITTER Mode Adjustments	5-10
5-18.	Matching of Quasi-rms and Average Detectors	5-10

Bulletin	APPENDICES
2010	SUPPRESSED-TONE PHASOR-DOMAIN MEASUREMENTS
1110	MODEL 2A/2B LINE IMPAIRMENT GENERATOR
1130	MODEL TIG-1/E TONE AND IMPAIRMENT GENERATOR
4110	TRANSPARENT LINE GENERATOR MODEL NNE 1000/R

LIST OF ILLUSTRATIONS

Fig.		Page
	Frontispiece Model PB-1C-D VF Line Analyzer	ii
2-1.	PB-1C-D Controls, Displays and Indicators	2-3
2-2.	PB-1C-D CRT Graticule	2-7
2-3.	Conversion From Percent to dB	2-7
3-1.	Oscillator, Simplified Functional Diagram	3-2
3-2.	PB-1C-D CRT and Speaker Circuits, Simplified Functional Diagram	3-4
3-3.	Frequency Meter Circuit, Simplified Functional Diagram	3-8
3-4.	Fast Input-Level Meter, Simplified Functional Diagram	3-8
3-5.	dB Card, Simplified Functional Diagram	3-10
3-6.	Multi-Mode Meter Circuits, Simplified Functional Diagrams	3-12
3-6A.	LEVEL Mode	3-12
3-6B.	NOISE Mode	3-12
3-6C.	NN SEP Mode	3-12
3-6D.	AMPL. JITTER and PHASE JITTER Modes	3-12
3-6E.	2ND H and 3RD H Modes	3-12
5-1.	Locations of Circuit Boards in PB-1C-D	5-3
5-2.	Locations of Adjustments on Mother Board	5-3
5-3.	Locations of Adjustments of Oscillator Card	5-3
5-4.	Locations of Adjustments on Meter Card	5-4
5-5.	Locations of Adjustments on Display Card	5-4
5-6.	Locations of Adjustments on High Voltage Card	5-4
5-7.	Locations of Adjustments on dB Card	5-5
5-8.	Locations of Adjustments on Output Card	5-5
5-9.	Locations of Adjustments on NPLL Card	5-5

PB-1C-D OPERATIONAL & CAUTION NOTES (Serial Numbers 250 up)

0-1. OPERATIONAL NOTES

a. Always check that one button in each group of pushbutton switches is depressed. There are four groups of pushbutton switches, labeled METER MODE, OSCILLATOR OUTPUT FREQUENCY, CRT MODE, and SCALE MULT. Fully depressing any non-depressed button in a group will lock that button down and release the previously depressed button in that group. However, it is possible to push two buttons in one group simultaneously, or to push one button far enough to release the previously depressed button but not far enough to lock itself, so that no button in the group remains depressed. This results in anomalous operation, and should be avoided.

b. Depress the momentary OUTPUT FREQ & LEVEL pushbutton to read oscillator output frequency on the frequency meter and (if the LEVEL button is depressed) oscillator output level on the multi-mode meter. If the OUTPUT FREQ & LEVEL button and any METER MODE button except LEVEL are depressed, the frequency meter will operate but the multi-mode meter will be blanked.

c. Multi-Mode Meter Out-of-Range Displays.

1. When the METER MODE NOISE button is depressed, the multi-mode meter displays the dBrnC level of the signal at the INPUT jack. The specified upper limit is 70dBrnC, but the meter will actually saturate at 80 ± 2dBrnC.

2. When any other METER MODE button is depressed, if the value of the parameter being measured by the multi-mode meter is above or below the specified range for that parameter, —— or EEE will appear. Such displays should never be encountered in normal measurements because the specified measurement ranges extend well beyond worst-case values.

0-2. CAUTION NOTES

a. Do not depress more than one momentary pushbutton at any time. There are five momentary pushbuttons, labeled NN SEP, OUTPUT FREQ & LEVEL, REMOVE FILTER, ADD LF, and HARMONIC SEPARATION. Depressing more than one of the momentary pushbuttons at the same time may cause anomalous operation. The exception to this are the NN SEP and REMOVE FILTER buttons. These are depressed simultaneously to read the flat weighted notched noise with narrow notch. Refer to Page 0-3 for a description of the notch width.

b. Do not attempt to read any function controlled by a red button unless the red DO NOT READ light is extinguished. All of the CRT MODE buttons, the HARMONIC SEPARATION button, and three of the METER MODE buttons (NN SEP, AMPL JITTER, and PHASE JITTER) are red; the remaining buttons on the panel are black. When the DO NOT READ indicator is dark, the CRT and all multi-mode meter displays are valid. When the DO NOT READ indicator is lit, the CRT, NN SEP, AMPL JITTER, PHASE JITTER and HARMONIC SEPARATION displays are invalid.

c. Do not attempt to read PHASE JITTER or AMPL JITTER in either the 2ND H or 3RD H CRT MODE. PHASE JITTER and AMPL JITTER can be read on the multi-mode meter only when one of the four CRT MODE VECTOR NOTCH buttons (4 TO 20, 20 TO 300, 4 TO 300, or UNFILT) is depressed but not when the 2ND H or 3RD H CRT MODE button is depressed. If a PHASE JITTER or an AMPL JITTER reading is attempted when either the CRT MODE 2ND H or 3RD H button is depressed, the multi-mode display will be blanked.

d. Do not attempt to read Second or Third Harmonic Separation on the multi-mode meter unless the 2ND H or 3RD H CRT MODE button, respectively, is depressed. Second or Third Harmonic Separation can be read on the multi-mode meter when the 2ND H or 3RD H button respectively and the LEVEL, NOISE, or NN SEP button are depressed. If a harmonic separation reading is attempted when any of the CRT MODE VECTOR NOTCH buttons is depressed, the multi-mode meter will be blanked.

e. Do not set the NNE switch to ATTEN except when the PB-1C-D is used with a Bradley Telcom NNE 1000 Series Transparent Line Generator. When the NNE switch is set to NORMAL, the SCALE CHANGE ON RED FUNCTIONS indicator is dark. When the NNE switch is set to ATTEN, the SCALE CHANGE ON RED FUNCTIONS indicator flashes, indicating that all functions controlled by red buttons (CRT MODE, NN SEP, AMPL JITTER, and PHASE JITTER) have been attenuated 14dB or by a factor of 5. When the SCALE CHANGE ON RED FUNCTIONS indicator is flashing, the audio output in the SPEAKER NOTCH MODE is reduced by the same amount.

f. Do not attempt to perform a self-check of the PB-1C-D equipped with external options (e.g., P/AR or NNE Sequencer) unless these add-ons are disconnected or turned off. The normal operation of the OUTPUT OSCILLATOR, for example, will be affected by the P/AR or the NNE Sequencer.

The P/AR unit must be switched to the OSC mode before PB-1C-D self-checks are performed. If the P/AR is left in the P/AR mode, the P/AR signal will be present at the PB-1C-D OUTPUT and sync cannot be obtained.

The NNE Sequencer must be switched to OFF before any PB-1C-D self-checks are performed. If the NNE Sequencer is left in the ENABLE mode, the NNE Sequencer will attempt to sequence through its automatic test cycle. The results will be unpredictable unless actually connected to a line under test (see BRTM Operating Manual #IN4140-684).

OPERATING NOTE

This instruction manual refers to units shipped on or after 9/20/84. The changes made at that time are described as follows.

1. The high pass filter required by PUB 41009 for level measurement (to reduce the contribution of 60Hz to the level reading) was moved to the input circuit where it operates for both the meter and the CRT display.

2. An additional notched noise mode was added for the NN SEP meter readout. This does not affect the CRT display. The control for this function replaces the NN FREQ button of earlier units.

60Hz FILTER

The purpose of 1. is to reduce the contribution of 60Hz to the CRT display in the unfiltered mode. As the PB-1C-D is used more and more on loops this change became desirable.

Moving the 60Hz filter to the input circuit affected operation as follows. When the filter is removed (by pressing the REMOVE FILTER button) the phase shift through the input circuit changes, causing a phase hit on the CRT. This is not a line phase hit. This phenomenon does not occur on earlier units because the filter was in series with only the meter circuit (and not with the CRT readout).

One other effect is noteworthy. This filter causes a small amount of PM/AM conversion at jitter frequencies above 300Hz because as the lower sideband goes below 700Hz (1000Hz-300Hz) it gets closer to the high pass filter corner frequency (200Hz). This is not a problem for 'authorized impairments', i.e., impairments as defined for conventional measurement instruments, and it can be removed by depressing the REMOVE FILTER button. The PM/AM conversion does generate useful diagnostic information as follows. With a predominate modulation impairment pattern (CRT in the UNFILTERED MODE), if depression of the REMOVE FILTER switch causes a noticeable change in tilt of the display, then the predominant jitter component is at higher frequencies. 300Hz modulation produces approximately 1.0° tilt; 600Hz produces approximately 10.0° tilt. In this case the true jitter reading is taken with the REMOVE FILTER button depressed.

WIDE NOTCH/NARROW NOTCH

The purpose of 2. is more complex. PUB 41009 defines a notch filter which can have up to 50Hz blocking bandwidth. No lower limit bandwidth is defined on the presumption that the narrower the better. The normal PB-1C-D notch is 8Hz wide, other manufacturers use a filter implementation which uses the entire allowable 50Hz. These latter instruments do not monitor notched noise components within ±25Hz of the test tone. A particular component which is thereby missed is phase jitter near the low end of the jitter band (4 to 20Hz). The PB-1C-D narrow notch does monitor these and other components of notched noise to within ±4Hz of the tone, hence the notched noise separation measured by the PB-1C-D, with narrow notch, may be from 1 to 2dB less (worse) than measurements made with other instruments. While this is a more accurate representation of the true notched noise, brand X instruments may pass a circuit which the PB-1C-D will not, i.e., the narrow notch reading is correct but is not preferred by some users. Therefore we added a wide notch measurement as well as the narrow notch measurement. When NN SEP is depressed, the result is a notched noise reading for the narrow band notch separation and, when not depressed, is a wideband notch separation reading. Both readings satisfy PUB 41009. The difference, for white noise, is approximately 1dB. Diagnostically a larger than normal difference indicates noise components close to the test tone, often low frequency phase jitter.

SECTION I
GENERAL INFORMATION

1-1. INTRODUCTION

1-2. Scope of Manual. This manual covers theory, operation and alignment of the PB-1C-D VF Line Analyzer, as well as analysis, identification and measurement of impairments displayed by the instrument.

1-3. The PB-1C-D VF Line Analyzer is the third generation of a series of instruments employing suppressed-tone phasor-domain CRT displays* for presenting, analyzing, identifying and measuring impairments induced on voice-frequency signals by the facilities through which those signals are transmitted. In addition to the phasor-domain CRT display which was employed in the earlier models PB-1 and PB-1C, the PB-1C-D has an instantaneous-level bar display, a digital frequency display and a digital multi-mode display; and push-button switches for selection of all functions, modes, and scale factors. The features of the PB-1C-D are listed in Par. 1-11, and its capabilities are listed in Par. 1-12ff.

1-4. NOTES ON THE PB-1C-D DISPLAYS

1-5. The PB-1C-D has two analog displays (a suppressed-tone phasor-domain CRT and an instant-reading level meter) for rapid diagnosis of problems on voice-frequency transmission facilities, and two digital displays (a multi-mode meter and a frequency meter) for rapid measurement of the impairments causing those problems. The total capability afforded by these displays makes the PB-1C-D the most powerful instrument available for troubleshooting voice-frequency transmission facilities. Within minutes, experienced users of the instrument can:

a. 'clear' facilities in cases of invalid complaints;

b. identify and measure impairments, in cases of valid complaints, for facilities personnel concerned with clearing troubles;

c. make go/no-go determinations of facilities, relative to modem requirements, for personnel concerned with data transmission.

1-6. The digital displays present numerical results of 'tariff' measurements made in accordance with sets of rules for weighting, detection, time-averaging, and quantification of impairments. The numbers provided by these displays can be compared with the numbers resulting from tariff measurements made by other personnel using other instruments at the transmission facility interfaces where maintenance responsibilities change. Note that tariff measurements, being time-averaged, are not made in real time; i.e., they are not instantaneously coincident with the measured phenomena.

* U.S. Patents, 3814868, 3906173, 3927281, 4021625, and 4061892. Other patents pending.

1-7. The phasor-domain CRT display does not make tariff measurements. It detects all impairments induced on a test tone by a facility, and presents each impairment at the instant of its occurrence, for visual demodulation by the eye of the operator. This real-time display permits simultaneous examination of all coincident impairments, as well as meaningful classification and identification of each impairment, and thus facilitates extremely rapid diagnosis. The phasor-domain method for examination of impairments is not limited by a set of rules for detection and time averaging as is required to produce a numerical display. The instrument therefore *does not become obsolete* whenever new impairments are discovered or rules for measurement are changed.

1-8. Unique 'facility-clearing' capability. What is being measured, when the PB-1C-D is monitoring a quiet line, and the phasor-domain display shows very little activity? In the unfiltered mode of operation, everything (i.e., every impairment) is being measured. Since *the phasor-domain display indicates which impairments are present and which impairments are absent,* the absence of activity on the display denotes a highly desirable condition. Of the existing impairments, one or two will usually predominate, depending on the type of facility; of no less importance is the fact that *all impairments absent from the display must be negligible.* The phasor-domain CRT display is thus the only existing means for positively 'clearing' facilities from suspicion of all impairments, including those which have already been defined and are now measured by conventional test equipment, as well as those which have not yet been defined and which either confuse, or are ignored by, conventional test equipment.

1-9. The PB-1C-D examines a facility in the same real-time way that modems use that facility, and permits direct comparison of facility performance with modem requirements. The instrument provides go/no-go screening capability for the relatively unskilled, and deep diagnostic information for the more sophisticated; all users of the PB-1C-D develop insight into the nature of impairments.

1-10. The phasor-domain technique has proven particularly useful in PCM and FDM carrier maintenance as a result of its ability to identify the 'mystery problems' which other instruments do not see, such as time variation of harmonic distortion, time variation of phase intercept distortion, narrow modulation hits, slow hits, harmonic hits, aliasing and compander problems, as well as others not yet identified. Digital displays, whether on conventional instruments or on the PB-1C-D, rely on time averaging, which masks any time-varying component at frequencies above a fraction of a hertz. Data sets making a thousand or more decisions per second respond to instantaneous (peak) impairments; thus, data-inimical harmonic distortion impairments may exist on PCM and FDM facilities which are not detected by conventional harmonic and four-tone nonlinear distortion measurements, or by conventional notched-noise measurements.

1-11. FEATURES OF THE PB-1C-D

a. Suppressed-Tone Phasor-Domain CRT Analog Display with pushbutton selection of four vector notch modes, two harmonic modes, and five sensitivity ranges.

b. Digital Multi-Mode Meter with pushbutton selection of input signal level, noise level, notched noise separation, second harmonic separation, third harmonic separation, phase jitter, amplitude jitter, and test-tone oscillator output level.

c. Digital Frequency Meter with pushbutton selection of input signal frequency, test-tone oscillator output frequency, and frequency of any predominant notched-noise component, e.g., single-frequency interference (SFI), harmonic of test-tone, or power-line pickup.

d. Fast Reading Input Level Meter for input signal level (range −42 to +9dBm), responds to bursts as short as 20 milliseconds, such as are encountered in polled multi-point data communications networks.

e. Internal Test-Tone Oscillator with adjustable output level (range −35 to +10dBm) and pushbutton selection of four fixed frequencies (1004Hz, 1004+2008Hz, 2008Hz, and 2713Hz) as well as one variable frequency (range 200 to 5000Hz). The 1004Hz tone is the basic test tone used by the PB-1C-D and other Bradley Telcom phasor-domain instrumentation. The 1004+2008Hz and 2008Hz tones are used to control remote Bradley Telcom NNE-type loopback devices, and the 2713Hz tone is used to control remote telco 829-type loopback devices. The 1004+2008Hz tone is also used for measuring phase-intercept distortion. The 200 to 5000Hz variable frequency is used to perform all of the test functions that would otherwise require a separate audio signal generator.

f. Acoustic Outputs at adjustable volume: input signal or notched noise (input signal minus tone).

g. Electrical Outputs for driving external recorders and/or Bradley Telcom 75 L/PA Printing Hit Counters.

h. Remote Test Facilities for use with remote Bradley Telcom NNE Series Transparent Line Generators: front panel pushbuttons provide tone commands for operation of remote NNEs, and scale-factor changes of all displays for direct readout of impairments relayed by remote NNEs; rear connector provides for operation with external Bradley Telcom test equipment.

1-12. CAPABILITIES OF THE PB-1C-D

1-13. The Suppressed-Tone Phasor-Domain CRT Display has the following capabilities:

a. Troubleshoots Transmission Facilities in One Pass, immediately disproving invalid complaints or identifying causes of valid complaints.

b. Enables Comprehensive Diagnosis by Detecting and Displaying All Impairments, including types ignored by other instruments. Tracks tone component of input signal, notches out tone, and *displays simultaneously in real time and true phase all the impairments that constitute the remaining 'notched noise', with those impairments meaningfully classified on a calibrated CRT graticule.*

c. Makes Go/No-Go Determination of Lines for Compatibility With Modems: Permits quantitative inspection of total in-phase and quadrature uncertainties caused by channel impairments.

d. Analyzes Complex Phenomena: separates, classifies and identifies each type of impairment, and measures magnitude, sense or direction, and duration. Distinguishes among impulse hits, phase hits, and gain hits. Distinguishes between phase jitter and amplitude jitter. Detects and measures phase and amplitude jitter outside the bandpass of other instruments, including low-frequency jitter down to 1Hz, and high-frequency jitter.

e. Identifies and Measures Test-Tone Parameters: level, frequency, frequency shift, frequency hits.

f. Identifies and Measures Tone-Correlated Amplitude Impairments: amplitude jitter, amplitude modulation, gain hits, gain steps, dropouts, fast dropouts, noisy dropouts; detects gain hits too short or too slow to be detected by conventional hit counters; indicates gain hit duration and direction.

g. Identifies and Measures Tone-Correlated Phase Impairments: phase jitter, phase modulation, phase hits, phase steps; detects phase hits too short or too slow to be detected by conventional hit counters; indicates phase hit duration and direction.

h. Identifies and Measures Non-Correlated Impairments: notched noise, impulse noise, single-frequency interference.

i. Identifies and Measures Distortion: second harmonic distortion, third harmonic distortion, time-varying phase-intercept distortion. (Continuous variation of phase-intercept distortion corresponds to frequency translation. Rapid variation of phase-intercept distortion causes data errors. Brief periods of rapid variation in phase-intercept distortion cause phase hits too slow to be seen by conventional hit counters, but cause frequency shifts large enough to confuse modems.)

j. Identifies The Location of Harmonic Distortion Sources with respect to (i.e., before or after) any frequency translation which may occur on a channel.

k. Identifies PCM Impairments: quantizing disturbances, foldback products, compandor mistracking, timing breakup.

l. Identifies Transmission Facilities, such as L, N, and T carrier, and copper pair, by their characteristic visual and acoustic 'signatures'.

m. Identifies and Measures Distant Impairments: i.e., between remote points, as well as between local and remote points, when used with NNE Transparent Line Generators placed at the remote points.

1-14. The Digital Multi-Mode Meter has the following capabilities:

a. Measures input signal levels from −45 to +9.9dBm, in the voice band, using average detection.

b. Measures input signal and background noise levels from 20 to 80dBrnC (−70 to −10dBm) over the voice band, with and without C-Message weighting, using quasi-rms detection.

c. Measures notched noise separation from −50 to 0dB over the voice band, with and without C-Message weighting, using quasi-rms detection.

d. Measures amplitude jitter from 0 to 50% over the 20 to 300 Hz band or the 4 to 300 Hz band.

e. Measures phase jitter from 0 to 50° over the 20 to 300Hz band or the 4 to 300Hz band.

f. Measures output level of the internal test oscillator, over its −40 to +10dBm amplitude range and 200 to 5000Hz frequency range.

g. Measures second harmonic separation from −50 to 0dB, for any test tone in the 930 to 1030Hz frequency range.

h. Measures third harmonic separation from −50 to 0dB, for any test tone in the 930 to 1030Hz frequency range.

1-15. The Digital Frequency Meter has the following capabilities:

a. Measures the frequency of any −35 to +10dBm input tone in the voice band.

b. Measures the frequency of any predominant notched noise component, e.g., single frequency interference, second or third harmonic of test tone, or power-line pickup.

c. Measures the frequency of the internal test-tone oscillator.

1-16. The Fast-Reading Input Level Meter has an 18-bar LED display which presents the level of the input signal, from −42 to +9dBm, even for bursts as short as 20 milliseconds.

1-17. The Loudspeaker presents the following acoustic outputs:

a. The total input;

b. The notched noise in the input (i.e., total input minus tone); this notched noise audio output increases the diagnostic capability of the instrument by permitting auditory and visual correlation of impairments. It is particulary useful for distinguishing correlated impairments (e.g., phase and gain hits) from uncorrelated impairments (e.g., impulse hits) which have different acoustic signatures.

c. A center-off position disconnects the loudspeaker circuit to eliminate the audio output without reducing the volume control setting.

1-18. NOTES ON MEASUREMENTS OF IMPAIRMENTS

1-19. Properties Versus Impairments. There is a fundamental distinction between **impairments** of transmission facilities (which are measured by the PB-1C-D) and **properties** of transmission facilities, as follows:

a. The properties of a transmission facility are its linear steady-state characteristics including gain, amplitude distortion (i.e., variation of gain with frequency), delay distortion, and return loss. Properties are not time-dependent. They can be completely characterized or described by sets of numbers or plotted curves (e.g., gain versus frequency) and can thus be compensated for as in adaptively equalized modems. Properties other than continuity or gain have therefore decreased in importance as causes of data-transmission problems.

b. The impairments of a transmission facility are all of its attributes, other than the properties, which cause degradation of signals. Impairments are complex and time-variable; they cannot be fully characterized by sets of numbers or plotted curves, and cannot be compensated for by circuitry. Impairments include noise, hits, jitter, distortion, and phase-intercept distortion. Each type of impairment has numerous sub-classifications.

1-20. Definitions of Impairments.

a. Tone Impairments

1. Frequency Hits are rapid changes in the frequency of the received test tone which may be followed by return to the original frequency.

2. Frequency Shift is a steady-state change in the frequency of each component of the signal passing through the facility.

b. Tone-Correlated Amplitude Impairments

1. Pure Amplitude Modulation of the test tone. (This impairment is virtually non-existent on telephone facilities.)

2. Amplitude Jitter includes the combined effects on the amplitude of the received tone caused by pure amplitude modulation and by additive, uncorrelated impairments such as noise and single-frequency interference.

3. Gain Hits are momentary changes in amplitude that return to approximately the original value. A **positive gain hit** is an increase in amplitude followed by a decrease to approximately the original value; a **negative gain hit** is a decrease in amplitude followed by an increase to approximately the original value. (Minimum **hit duration** for a gain hit to be counted on a conventional hit counter is 4 milliseconds. Many gain hits occur which are shorter than 4 milliseconds.)

4. Dropouts are negative gain hits of at least 12dB which persist for at least 4 milliseconds.

5. Gain Steps are rapid changes in amplitude that do not return to the original value.

c. Tone-Correlated Phase Impairments

1. Pure Phase Modulation is angular modulation of the test tone.

2. Phase Jitter includes the combined effects on the phase of the received tone caused by pure angle modulation and by additive, uncorrelated impairments such as noise and single-frequency interference.

3. Phase Hits are momentary changes in phase that return to approximately the original value. (Minimum hit duration must be 4 milliseconds for a phase hit to be counted on a conventional hit counter. Many phase hits occur which are shorter than 4 milliseconds.)

4. Phase Steps are rapid changes in phase that do not return to the original value.

d. Non-Correlated Impairments

1. Background Noise

2. Single-Frequency Interference includes undesired spurious steady tones, but does not include phenomena such as multifrequency tone bursts that may result from crosstalk or multifrequency signaling on other channels.

3. Impulse Noise is a momentary component of the received signal noise that exceeds rms background noise level in a given frequency band by 12dB or more.

e. Distortion

1. 2nd Harmonic Distortion: single tone at twice the test-tone frequency.

2. 3rd Harmonic Distortion: single tone at three times the test-tone frequency.

3. Phase Intercept Distortion

f. PCM Impairments

1. Quantizing Disturbances

2. Timing Jitter

3. Aliasing or Foldback Products

4. Compandor Mistracking

5. Loss of Frame

1-21. Notched Noise Measurements of Impairments.

a. Transmission facilities carrying signals (the 'data stream') between data sets may induce on those signals impairments that cause the data sets to make errors when receiving those signals. It is therefore necessary to evaluate the transmission facilities for such error-causing impairments. Since data sets make decisions in the presence of signals, the transmission facilities must be evaluated while carrying signals. In the absence of a signal the only impairments generated in a facility are additive, e.g., **background noise, impulse noise, crosstalk, etc. A signal offers the facility something to modulate, jitter, quantize, or distort, and thus on which to induce impairments (e.g., phase hits, gain hits, phase jitter, amplitude jitter, harmonic distortion, nonlinear distortion, quantizing noise, timing jitter, aliasing or foldback products, frequency translation, etc.) which are absent in the absence of a signal. Therefore, to meaningfully test a facility for data transmission capability a signal must be sent through it, and the received signal at the other end must be examined for impairments induced on that signal by the facility.**

b. The probing signal for testing facilities is generally a nominal 1000Hz (often actually 1004 or 1010Hz) sinusoidal tone. Test-tone sources used in notched-noise measurements must have pure and stable outputs without noise, harmonics, phase jitter, or amplitude jitter, because such impairments of the original tone at the transmit end are indistinguishable at the receive end from impairments induced on the tone by the facility. Impairments of the original tone will therefore increase the measured values of impairments ascribed to the facility. For this reason the test-tone oscillators in the PB-1C-D as well as in all other Bradley Telcom instrumentation containing tone sources (NNE Series Transparent Line Generators, TTL Series Touch-Tone Addressable Loopback Transponders, etc.) are designed to provide outputs of extremely high purity and stability.

c. When a sinusoidal test tone is transmitted over a voiceband facility, the signal received at the other end of the facility contains a steady-state (or quiet) tone corresponding to the test tone, plus all impairments induced on the tone by the facility, including tone-correlated impairments (AM and PM; quantizing noise; harmonics; and hits, steps, and dropouts) as well as non-correlated impairments (SFI, noise, and power-frequency pickup). Since the impairments in the received signal are generally much smaller in magnitude than the test tone, it is difficult to measure those impairments in the presence of the tone, which tends to obscure them. Therefore, in notched-noise measurements, the test tone is removed from the received signal, and the remainder of the signal (called the 'notched noise', because the tone is usually removed with a notch filter) is examined. The notched noise contains all of the impairments that were induced on the test tone by the facility , as well as those additive components which exist whether or not a signal or test tone is present, including complete information concerning the magnitude, sense or direction, duration, and phase of each impairment. All non-real-time methods of examining notched noise lose this information, because such methods employ time-averaging. Only the phasor-domain method preserves this information, because it employs instantaneous detection that permits real-time display of each impairment with its exact phase and amplitude relative to the tone.

1-22. Suppressed-Tone Phasor-Domain Analysis of Notched Noise. The suppressed-tone phasor-domain method (1) tracks the frequency and (2) normalizes the amplitude of the quiet tone in the received signal; (3) eliminates the tone from the received signal, leaving only normalized notched noise; (4) resolves the normalized notched noise into in-phase and quadrature components; and (5) displays them on a cathode-ray tube so that they can be separately identified and measured by means of calibrated scales on the CRT graticule.

a. Suppressed-tone phasor-domain instrumentation accomplishes the foregoing by means of two high-gain closed loops, an automatic gain control (AGC) loop and a notch phase-lock loop (NPLL), which are interconnected to operate as a narrow-band notch filter that automatically tracks and suppresses the steady-state or quiet-tone component of a received signal.

b. The NPLL tracks the frequency of the quiet tone and generates two orthogonal reference tones; one in phase with the quiet tone, and one in quadrature with the quiet tone.

c. The AGC loop tracks the level of the quiet tone and normalizes the received signal by amplifying the quiet tone to the same amplitude as that of the in-phase reference tone. Since the in-phase reference tone is of the same amplitude and phase as the quiet tone, it is equivalent to the quiet tone, and may be subtracted from the normalized received signal, leaving normalized notched noise, 'NNN' (i.e., normalized received signal minus quiet tone) containing only the normalized impairments. This is equivalent to eliminating the quiet tone by means of an extremely narrow notch filter, but has the advantage that it automatically follows or tracks variations of the quiet tone frequency.

d. The normalized notched noise is resolved into in-phase and quadrature components that are fed to the vertical and horizontal deflection amplifiers, respectively, of a cathode-ray tube. Since the notched noise is normalized, the vertical and horizontal deflections can be measured against the calibrated scales of a graticule located in front of the CRT screen.

1-23. SIMPLIFIED BLOCK DIAGRAM OF PB-1C-D PHASOR-DOMAIN CIRCUITS (See Fig. 3-2)

The block diagram of Figure 3-2 shows how the suppressed-tone phasor-domain method is implemented by means of two interconnected loops, the automatic gain-control (AGC) loop and the notched phase-lock loop (NPLL).

a. The received signal, comprising the quiet tone ($V_r \cos \omega t$) and the accompanying impairments induced by the facility, is fed to the AGC amplifier, which amplifies the received signal to the level at which the quiet tone is equal to the in-phase reference tone ($V_{ref} \cos \omega t$) from the NPLL. The quiet tone and its impairments, which are thus also normalized in amplitude, are fed to the (+) input of the difference amplifier, as well as to the NPLL.

b. The NPLL locks to the quiet tone ($V_r \cos \omega t$) in the normalized received signal and generates two synchronous reference tones; a reference tone ($V_{ref} \cos \omega t$) in phase with the quiet tone, and a reference tone ($V_{ref} \sin \omega t$) in quadrature with the quiet tone. The in-phase reference tone ($V_{ref} \cos \omega t$) is fed to the (−) input of the difference amplifier and also to one input of the AGC controller; the quadrature reference tone ($V_{ref} \sin \omega t$) is fed to the display phase-lock loop (DPLL).

c. Since the (+) input to the difference amplifier is the normalized signal ($V_r \cos \omega t$ + impairments), and the (−) input is the reference tone ($V_{ref} \cos \omega t$), the output of the difference amplifier will be the normalized signal minus the quiet tone, or the normalized impairments alone. **Impairments remaining after the quiet tone component of the received signal is removed, suppressed, or 'notched' from the signal, are conventionally called 'notched noise'. Since the quiet tone is notched from the normalized** received signal, the remaining impairments are referred to as **normalized notched noise,** (NNN).

1-24. The NNN voltage from the difference amplifier is fed to the AGC multiplier where it is multiplied by the in-phase reference tone ($V_{ref} \cos \omega t$) from the NPLL to measure that component of NNN which is in phase with the quiet tone. This is the quantity the average value of which is to be reduced to zero by the AGC amplifier in order to leave only NNN at the difference amplifier output.

1-25. The quadrature output ($V_{ref} \sin \omega t$) of the NPLL is used to synchronize the display phase-lock loop (DPLL). Depending on the setting of the CRT MODE buttons, the DPLL is commanded to phase-lock to the tone (when any one of the four VECTOR NOTCH buttons is depressed), to the second harmonic of the tone (when 2ND H is depressed) or to the third harmonic of the tone (when 3RD H is depressed). If the DPLL is locked to the tone, its outputs are $V_{ref} \cos \omega t$ and $V_{ref} \sin \omega t$; if it is locked to the second harmonic of the tone, its outputs are $V_{ref} \cos 2\omega t$ and $V_{ref} \sin 2\omega t$; and if it is locked to the third harmonic, its outputs are $V_{ref} \cos 3\omega t$ and $V_{ref} \sin 3\omega t$. The cosine (in-phase) output of the DPLL is fed to one input of the cosine multiplier and the sine (quadrature) output of the DPLL is fed to one input of the sine multiplier. The normalized notched noise (NNN) output of the difference amplifier is fed to the other input of each multiplier.

1-26. The outputs of the cosine and sine multipliers are (in any one of the four VECTOR NOTCH modes) NNN cos ωt and NNN sin ωt, or (in the 2ND H mode) NNN cos $2\omega t$ and NNN sin $2\omega t$, or (in the 3RD H mode) NNN cos $3\omega t$ and NNN sin $3\omega t$. In the 4 TO 20, 20 TO 300, 4 TO 300, or UNFILTered VECTOR NOTCH modes, the cosine and sine multiplier outputs NNN cos ωt and NNN sin ωt are fed through filters of the designated bandwidths to the CRT vertical and horizontal deflection circuits, respectively. (The UNFILTered bandwidth is that of the entire voice-frequency band). In the 2ND H or 3RD H mode, the cosine and sine multiplier outputs NNN cos $2\omega t$ and NNN sin $2\omega t$ or NNN cos $3\omega t$ and NNN sin $3\omega t$ are fed through low-pass 0-3Hz filters to the CRT vertical and horizontal deflection circuits.

1-27. The time constants of the AGC Loop and of the notch and display phase-lock loops are chosen so that the loops operate rapidly enough to recover from transients within the 1/8 second dead-zone interval of hit counters, but do not operate so rapidly that they mask hits, steps, or other transients.

SECTION II
DESCRIPTION OF PB-1C-D V-F LINE ANALYZER

2-1. EXTERNAL DESCRIPTION (See Frontispiece)

2-2. The PB-1C-D is contained in a portable case 17-1/2″ wide, 5-1/4″ high, and 12-1/2″ deep, exclusive of panel controls and handles. A tilt stand on the underside of the case permits the instrument to be tilted up for ease of viewing the displays and operating the controls, and bumpers at the rear of the case permit the unit to be stood with panel up for use in the narrow aisles between equipment racks. Available options include a carrying case, and an adapter kit for mounting the PB-1C-D in a 19″ rack (see Par. 2-24). The feet and tilt-stand assembly are outside the 5-1/4″ height and must be removed to mount the PB-1C-D in a 5-1/4″ high panel slot.

2-3. Front of Instrument (See Figure 2-1).

2-4. The following items are located on the front panel:

a. The screen, graticule, and bezel of a cathode-ray tube. In a column at the left of the CRT are a DO NOT READ CRT & RED FUNCTIONS indicator and three controls (INTENSITY, FOCUS, and SCALE ILLUMination), and at the right of the CRT are a column of six interlocked red CRT MODE pushbuttons, a column of five interlocked black SCALE MULTiplier pushbuttons, and a loudspeaker.

b. At the left of the panel are, from top to bottom: a digital frequency display and two black related momentary pushbuttons labeled NN SEP and OUTPUT FREQuency & LEVEL; a digital multi-mode display and related pushbuttons (a row of five interlocked METER MODE pushbuttons, of which the three at the right are red, and the two at the left are black; and two black momentary pushbuttons labeled REMOVE FILTER and ADD LF); and controls for an internal test-tone oscillator (OUTPUT LEVEL potentiometer; a row of five interlocked black OSCILLATOR OUTPUT FREQUENCY pushbuttons, and a 200 TO 5000Hz potentiometer).

c. Along the bottom of the panel are, from left to right: a POWER toggle switch and a fusepost; a SCALE CHANGE ON RED FUNCTIONS indicator and an NNE toggle switch (for testing at remote points by means of external Bradley Telcom Transparent Line Generators); fast INPUT LEVEL bar display meter; five 310 jacks labeled OUTPUT, INTERCONNECT A, INTERCONNECT B, XY OUT, and XY IN; a red HARMONIC SEPARATION momentary pushbutton, a 310 jack labeled INPUT; a 600Ω/BRIDGE toggle switch and a HOLD COIL toggle switch; a SINGLE AXIS toggle switch; a SPEAKER VOLUME control; and a SPEAKER MODE toggle switch.

d. Note the following:

1. Simultaneously depressing more than one of the momentary pushbuttons labeled OUTPUT FREQ & LEVEL, REMOVE FILTER, ADD LF, and HARMONIC SEPARATION at the same time may cause invalid readings. Simultaneous depression of the NN SEP and the REMOVE FILTER buttons is a valid operating mode.

2. Fully depressing any button in any of the interlocked groups (METER MODE, OSCILLATOR OUTPUT FREQUENCY, CRT MODE, and SCALE MULT) will lock that button down and release the previously depressed button in that group. Although it is impossible for more than one button in each group to remain down, it is possible to partially depress any other button in that group so that it releases the previously depressed button without remaining down itself. Thus all buttons in the group can remain up, causing anomalous operation and erroneous or invalid displays.

3. The multi-mode meter display will be blanked when invalid combinations of buttons in the interlocked groups of buttons are depressed and, with one exception, will display three E's when the measured value of a parameter is below the specified lower limit of the meter range for that parameter, or two minus signs when the measured value is above the specified upper limit. The single exception is the METER MODE NOISE display, which saturates at an upper limit of about 80 ± 2dBrnC.

2-5. Side And Rear Of Instrument

2-6. The following items are located at the side and rear of the instrument:

a. A three-prong recessed-male ac power receptacle is located on the left side.

b. A 25-pin EIA connector is located at the rear. This permits: (1) rear connections from most of the front-panel jacks to a remote patch panel, or to external instruments such as hit counters and jitter meters; (2) remote selection of PB-1C-D oscillator frequencies.

2-7. FUNCTIONS OF CONTROLS, DISPLAYS, AND INDICATORS

2-8. POWER Switch and Fuse. When the PB-1C-D is connected to a power source of rated voltage and frequency by means of a cable plugged into the three-prong receptacle at the left side, the instrument is turned ON and OFF by means of the POWER toggle switch. The instrument is protected by a 0.5A fuse adjacent to the POWER switch.

2-9. INPUT Jack, Switches, and Display. Input signals to be analyzed are fed to the instrument through the 310 INPUT jack. Associated with the INPUT jack are a 600Ω/BRIDGE toggle switch, a HOLD COIL toggle switch, and the fast INPUT LEVEL display.

a. HOLD COIL Switch. When this toggle switch is set to IN, it connects a holding coil across the INPUT jack; when set to OUT, it disconnects the holding coil from the input. The holding coil has a dc resistance of 180 ohms and inductances of 2 henries at 60mAdc and 1.3 henries at 100mAdc.

b. 600Ω/BRIDGE Switch. When this toggle switch is set to 600Ω, it connects a 600 ohm termination across the INPUT jack. The 600 ohm terminating resistor is rated to withstand a 48Vdc central office battery. When the switch is set to BRIDGE, the INPUT jack presents a high input impedance to the input line. The BRIDGE input impedance is greater than 40 kilohms when the HOLD COIL switch is set to OUT, but is reduced by the parallel impedance of the holding coil when the HOLD COIL switch is set to IN.

c. Fast INPUT LEVEL Meter. This 18-bar LED display presents the nearly instantaneous level of the input signal over the range −42 to +9dBm, responding to bursts as short as 20 milliseconds, such as are encountered in polled multi-point data communications networks.

2-10. Digital Frequency Meter and Controls. The four-digit frequency meter measures and displays the frequencies of selected signals over the range 40 to 5000Hz, if the levels of those signals are between −35 and +10dBm. The display is updated twice each second. The signals whose frequencies are to be displayed in the digital frequency meter are selected by means of the OUTPUT FREQ & LEVEL pushbutton. This button causes the frequency of the internal oscillator to be displayed on the frequency meter. When the OUTPUT FREQ & LEVEL pushbutton is not depressed, the input signal is displayed on the frequency meter.

2-11. Digital Multi-Mode Meter and Controls. The 3 1/2-digit multi-mode meter displays the data selected by five interlocked METER MODE pushbuttons (labeled LEVEL, NOISE, NN SEP, AMPL. JITTER, and PHASE JITTER) and five momentary pushbuttons (labeled REMOVE FILTER, ADD LF, NN SEP, OUTPUT FREQ & LEVEL, and HARMONIC SEPARATION) as follows:

a. The LEVEL button causes the dBm level of voice-frequency input signals to be displayed on the multi-mode meter. The range is −45 to +9.9dBm, as measured through a 200Hz high-pass filter and a high-frequency noise protection filter. When the REMOVE FILTER button is also depressed, the 200Hz high-pass filter is removed, permitting more accurate level measurements at low frequencies.

b. The NOISE button causes the dBrnC level of the noise in the input signal to be displayed on the multi-mode meter. The range is 20 to 70dBrnC (−70 to −20dBm), as measured through a filter with C-Message weighting. When the REMOVE FILTER button is also depressed, the input noise level is measured with the C-Message filter disconnected, and the indications are then in dBrn.

c. The red NN SEP button causes the notched noise separation in dB (i.e., level of notched noise in dB relative to level of quiet tone in the input signal) to be displayed on the multi-mode meter if the CRT is in any VECTOR NOTCH mode. The range is −50 to 0dB, as measured through a C-Message and wide-band notch filter. When the REMOVE FILTER button is also depressed, the C-Message filter is disconnected. When the momentary pushbutton NN SEP PUSH FOR NARROW NOTCH is depressed, the wide-band filter is removed. Note the following

1. The notched noise separation measurement is valid only if the DO NOT READ CRT & RED FUNCTIONS indicator is off

2. The displayed value of notched noise separation is 14dB less than the input value when the NNE switch is set to ATTEN and the SCALE CHANGE ON RED FUNCTIONS indicator is flashing.

d. The red AMPL. JITTER button causes the percent amplitude jitter of the input signal to be displayed on the multi-mode meter if the CRT is in any VECTOR NOTCH mode. The range is 0 to 50%. The measurement bandwidth is 20 to 300Hz or (if the ADD LF button is also depressed) 4 to 300Hz. Note the following:

1. The multi-mode meter will display amplitude jitter only if the AMPL. JITTER button and one of the four CRT MODE VECTOR NOTCH buttons are depressed. The bandwidth of the amplitude jitter measurement is 20 to 300 Hz (or 4 to 300Hz if the ADD LF button is also depressed), regardless of which VECTOR NOTCH button is depressed.

2. The amplitude jitter measurement is valid only if the DO NOT READ CRT & RED FUNCTIONS indicator is off.

3. The multi-mode meter will be blanked if the AMPL. JITTER button and either the 2ND H or the 3RD H CRT MODE button are depressed.

4. The displayed value of amplitude jitter is the input value divided by 5 when the NNE switch is set to ATTEN and the SCALE CHANGE ON RED FUNCTIONS indicator is flashing.

e. The red PHASE JITTER button causes the phase jitter in degrees of the input signal to be displayed on the multi-mode meter if the CRT is in any VECTOR NOTCH mode. The range is 0 to 50°. The measurement bandwidth is either 20 to 300Hz or (if the ADD LF button is also depressed) 4 to 300Hz. Note the following:

1. The multi-mode meter will display phase jitter only if the PHASE JITTER button and one of the four CRT MODE VECTOR NOTCH buttons are depressed. The bandwidth of the phase jitter measurement is 20 to 300Hz (or 4 to 300Hz if the ADD LF button is also depressed), regardless of which CRT MODE VECTOR NOTCH button is depressed.

2. The phase jitter measurement is valid only if the DO NOT READ CRT & RED FUNCTIONS indicator is off.

3. The multi-mode meter will be blanked if the PHASE JITTER button and either the 2ND H or 3RD H CRT MODE buttons are depressed.

4. The displayed value of phase jitter is the input value divided by 5 when the NNE switch is set to ATTEN, and the SCALE CHANGE ON RED FUNCTIONS indicator is flashing.

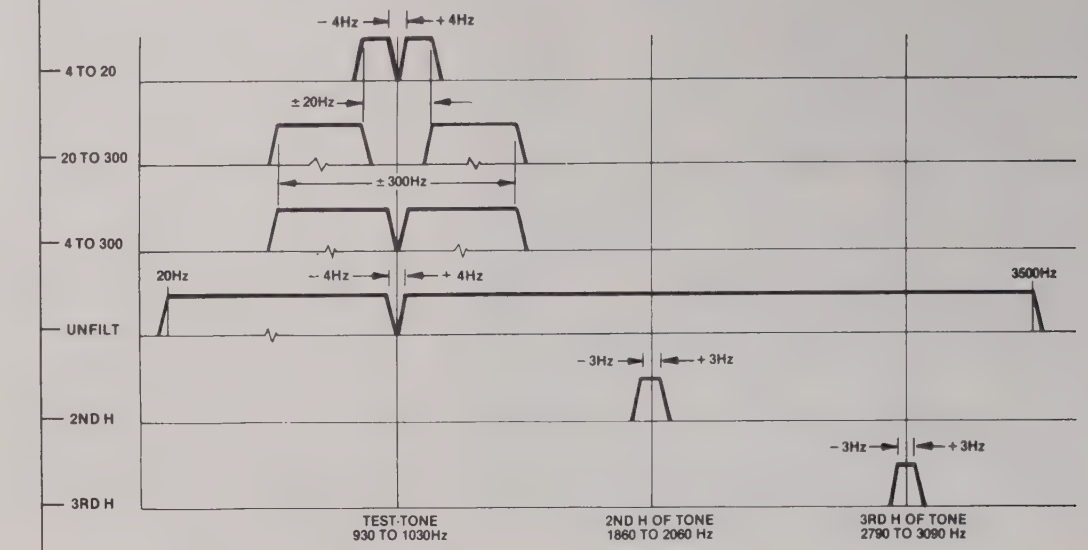
f. The OUTPUT FREQ & LEVEL button causes the oscillator output level in dBm to be displayed on the multi-mode meter, if the METER MODE LEVEL button is depressed. The OUTPUT FREQ & LEVEL button also causes the oscillator output frequency in Hz to be displayed on the digital frequency meter

FIGURE 2-1. MODEL PB-1C-D CONTROLS, DISPLAYS AND INDICATORS

- DIGITAL MULTI-MODE METER displays quantities selected by **METER MODE** buttons and other buttons as described below:
- Input Signal **LEVEL** (range –45 to + 9.9dBm), average-detected. Depress **REMOVE FILTER** button to remove 60Hz rejection filter.
- **NOISE** Level (range 20 to 80dBrnC), C-Message weighted, quasi-RMS detected. Depress **REMOVE FILTER** button to remove C-Message weighting.
- Notched-Noise Separation, **NN SEP** (range –50 to 0 dB), C-Message and wide-band weighed, quasi-RMS detected. Depress **REMOVE FILTER** button to remove C Message weighing. Depress **NN SEP PUSH FOR NARROW NOTCH** to remove wide band notch filter.
- **AMPL JITTER** (range 0 to 50%) in 20 to 300Hz band, peak-to-peak detected, in any **VECTOR NOTCH CRT MODE**. Depress **ADD LF** button for 4 to 300Hz.
- **PHASE JITTER** (range 0 to 50°) in 20 to 300Hz band, peak-to-peak detected, in any **VECTOR NOTCH CRT MODE**. Depress **ADD LF** button for 4 to 300Hz.
- Oscillator Output level (range –35.0 to + 10dBm,) when **OUTPUT FREQ & LEVEL** and **METER MODE LEVEL** buttons are depressed.
- Second Harmonic Separation (range –50 to 0dB), when **2ND H CRT MODE** and **HARMONIC SEPARATION** buttons are depressed, and if **LEVEL**, **NOISE**, or **NN SEP METER MODE** button is depressed.
- Third Harmonic Separation (range –50 to 0dB), when **3RD H CRT MODE** and **HARMONIC SEPARATION** buttons are depressed, and if **LEVEL**, **NOISE**, or **NN SEP METER MODE** button is depressed.

- **DO NOT READ CRT & RED FUNCTIONS** indicator is off, and all displays are valid, when AGC and phaselock loops are tracking input signal (range 930 to 1030Hz, – 40 to + 10dBm). Indicator lights when loops are not tracking input signal.
- **INTENSITY** control adjusts brightness of CRT spot.
- **FOCUS** control adjusts size of CRT spot.
- **SCALE ILLUM**ination control adjusts brightness of CRT graticule scales.

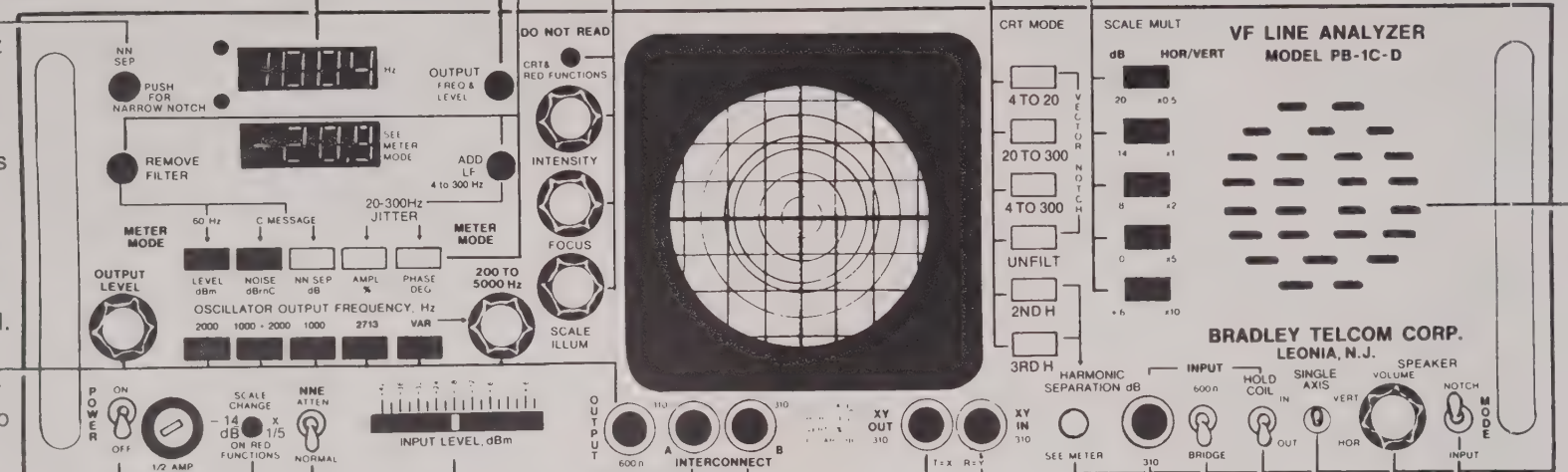
CRT MODE buttons select the following frequency bands:



SCALE MULTiplier buttons select the following ranges:

– 20dB	– 14dB	– 8dB	– 0dB	+ 6dB
x0.5	x1	x2	x5	x10

- **NN SEP** depressed reduces notch width from 50Hz to 8 Hz in width. Wide notch provides agreement with other test equipment, narrow notch provides more accurate result.
- DIGITAL FREQUENCY METER displays frequencies as follows:
- Input Signal Frequency (range 40 to 5000Hz) when **OUTPUT FREQ & LEVEL** button is not depressed.
- Oscillator Output Frequency (range 200 to 5000Hz) when **OUTPUT FREQ & LEVEL** button is depressed.



- Oscillator **OUTPUT LEVEL** control. Depress **OUTPUT FREQ & LEVEL** and **METER MODE LEVEL** buttons to read oscillator output level on Multi-Mode Meter.
- **OSCILLATOR OUTPUT FREQUENCY** buttons select **2000Hz, 1000 + 2000Hz, 1000Hz, 2713Hz,** and **VAR**iable output frequency.
- **200 to 5000Hz** control is operative when **VAR** button is depressed. Depress **OUTPUT FREQ** & **LEVEL** button to read oscillator output frequency on Frequency Meter.
- Oscillator 600Ω **OUTPUT** jack

- **POWER ON/OFF** switch and fuse.

- **NNE ATTEN/NORMAL** switch. Usually set to **NORMAL**; set to **ATTEN** for notched-noise-enhanced input from remote Bradley Telcom Transparent Line Generators.
- **SCALE CHANGE ON RED FUNCTIONS** indicator flashes when **NNE** switch is set to **ATTEN.**

- **INTERCONNECT A** and **B** jacks provide outputs for other instruments, such as the Bradley Telcom 75L/PA Printing Hit Counter. **INTERCONNECT A** Tip = Phase-Lock Local Oscillator; INTERCONNECT A Ring = Normalized Input; **INTERCONNECT B** Tip = Normalized Notched Noise; INTERCONNECT B Ring = Input Repeat.

- Fast **INPUT LEVEL** Bar Display (range – 42 to + 9dBm) responds to input signal bursts as short as 20 milliseconds, for monitoring polled multi-point data communications networks.

- **SPEAKER**
- **SPEAKER VOLUME** control adjusts loudness of acoustic output.
- **SPEAKER MODE** Switch determines whether acoustic output is **NOTCH**ed noise or **INPUT** signal repeat. Center-off position disconnects audio output.

- **SINGLE-AXIS** Switch has three-positions; spring-return center position (both X and Y deflections), VERT position (Y deflection only), and HOR position (X deflection only).

- **INPUT** Jack accepts signals to be analyzed. Input impedance determined by settings of **600 Ω /BRIDGE** Switch and **HOLD COIL** Switch.
- **600 Ω /BRIDGE** Switch sets input impedance to 600 Ω or Bridging.
- **HOLD COIL** Switch **IN** connects Holding Coil across input; **OUT** disconnects Holding Coil from input.

- **HARMONIC SEPARATION** button. See Second Harmonic Separation and Third Harmonic Separation under DIGITAL MULTI-MODE METER.

- **XY IN** Transfer Jack, when patched, connects patch cord to inputs of CRT deflection amplifiers so instrument can be used as an X-Y oscilloscope or vectorscope. Tip = H or X input; Ring = V or Y input.

- **XY OUT** Jack make available for external recording the voltages at the inputs of the CRT Vertical and Horizontal deflection amplifiers. Tip = H or X input voltage, Ring = V or Y input voltage.

g. The HARMONIC SEPARATION button causes the second or third harmonic separation in dB to be displayed on the multi-mode meter when the 2ND H or 3RD H CRT MODE button, respectively, is depressed, if the METER MODE LEVEL, NOISE, or NN SEP button is depressed. Note that if the HARMONIC SEPARATION button is depressed when the METER MODE AMPL. JITTER or PHASE JITTER button is depressed, or when any one of the four CRT MODE VECTOR NOTCH buttons is depressed, the meter will be blanked.

2-12. Oscillator Controls, Displays, and Jack. This group comprises a one-turn OUTPUT LEVEL control, five interlocked OSCILLATOR OUTPUT FREQUENCY pushbuttons, a ten-turn 200 TO 5000Hz variable frequency control, a 310 OUTPUT jack, and the OUTPUT FREQ & LEVEL pushbutton described above.

a. The OUTPUT LEVEL control adjusts the oscillator output voltage appearing at the OUTPUT jack to any level between −40 and +10dBm. The output level can be set precisely by depressing the OUTPUT FREQ & LEVEL button to monitor the level on the multi-mode meter while adjusting the OUTPUT LEVEL control.

b. The OUTPUT jack has a balanced 600 ohm output impedance, dc-blocked for up to 160Vdc.

c. The OSCILLATOR OUTPUT FREQUENCY pushbuttons select the frequency of the oscillator signal appearing at the OUTPUT jack. The frequencies selected by the buttons are: 2008Hz; 1004Hz and 2008Hz at −10dB relative to the 1004Hz tone; 1004Hz; 2713Hz; and VARiable, determined by the setting of the 200 TO 5000Hz control. The purposes of these frequencies are as follows:

1. The 1004Hz tone is the basic test tone used with the PB-1C-D and other Bradley Telcom phasor-domain instrumentation.

2. The 2008Hz and 1004 + 2008Hz tones are used to control remote Bradley Telcom NNE-type loopback devices. Detailed explanations of such uses are given in the instructions for the devices.

3. The 2713Hz tone is used to control remote 829-type tone-operated loopback devices, which are usually installed at the customer site, on the telco side of the telco-customer interface, in private line circuits. The 2713Hz tone is transmitted from any VF appearance to the loopback device at the customer site, and is used both to start and to end loopback tests. If the 2713Hz tone is sent for a maximum of five seconds and then stopped, the loopback device will automatically form a loop when the 2713Hz tone stops. A test tone (e.g., 1004Hz) may then be launched for the loopback test. After the loopback test has been performed, the loopback connection can be opened by sending a 2713Hz tone until the return tone in the incoming line ceases. Note: *Never transmit 2713Hz tone on multipoint circuits because inadvertent loops may be formed which subsequently cannot be re-opened by remote control.*

4. The 200 TO 5000Hz variable tone is used to perform all of the test functions that would otherwise require a separate audio signal generator.

d. The 200 TO 5000Hz control is a ten-turn potentiometer that controls the oscillator output frequency when the VAR button is depressed. The frequency can be set precisely by depressing the OUTPUT FREQ & LEVEL button to monitor the frequency on the digital frequency meter while adjusting the 200 TO 5000Hz control.

e. The OUTPUT FREQ & LEVEL button, as stated in Par. 2-11f, causes the oscillator output frequency to be displayed on the digital frequency meter and (if the METER MODE LEVEL button is depressed) the oscillator output level to be displayed on the multi-mode meter.

2-13. CRT GRATICULE, CONTROLS, AND INDICATOR

In a column at the left of the CRT are, from top to bottom, a DO NOT READ CRT & RED FUNCTIONS indicator and three controls labeled INTENSITY, FOCUS, and SCALE ILLUM. At the right of the CRT are a column of six interlocked red CRT MODE pushbuttons and a column of five interlocked black SCALE MULT pushbuttons. Along the bottom of the panel, below and to the right of the CRT, are two 310 jacks labeled XY OUT and XY IN, and a red HARMONIC SEPARATION momentary pushbutton; further to the right is a SINGLE-AXIS toggle switch.

a. The DO NOT READ CRT & RED FUNCTIONS indicator is off, and all displays are valid, when the phasor-domain AGC and phase-lock loops are locked to the input signal. These loops will acquire and track input frequencies between 930 and 1030Hz, at input levels between −40 and +10dBM. When the AGC and phase-lock loops are not all locked to the input signal, the DO NOT READ CRT & RED FUNCTIONS indicator will light, warning that all CRT MODEs and the NN SEP, AMPL. JITTER, and PHASE JITTER presentations of the digital multi-mode meter are invalid.

b. The INTENSITY and FOCUS controls permit continuous variation of the CRT spot brightness and spot size, respectively. Note the following:

1. Interaction between INTENSITY and FOCUS controls may necessitate readjustment of one when the setting of the other is changed.

2. To avoid burning center of CRT screen if spot remains undeflected for long periods, reduce setting of INTENSITY control. Do not change setting of FOCUS control, even though the lower-intensity spot may be defocused. When intensity is increased to its former level, the spot will again be in focus.

c. The SCALE ILLUM control permits continuous variation of the graticule scale brightness.

d. The graticule (see Figure 2-2) mounted behind the CRT bezel and in front of the CRT screen has three sets of illuminated scales that are calibrated as follows:

1. The vertical scale is linearly divided by equally-spaced horizontal lines that are numbered along the vertical axis from bottom to top, as follows: −6, −4, −2, (0), +2, +4, and +6. The vertical scale represents percent amplitude jitter, and is read zero to peak.

2. The horizontal scale is linearly divided by equally-spaced vertical lines that are numbered along the horizontal axis from left to right as follows: −3, −2, −1, (0), +1, +2, and +3. The horizontal scale represents angular degrees of phase jitter, and is read peak to peak.

3. The circular or polar scale is logarithmically divided by concentric circles that are numbered inward along a diagonal from the lower left as follows: −10, −12, −14, −16, and −20. The innermost circle, representing −30, is not numbered on the graticule. The polar scale represents dB separation from received tone and is used to read notched noise separation, second harmonic separation, and third harmonic separation.

2-14. CRT MODE Pushbuttons. There are six red CRT MODE pushbuttons; four VECTOR NOTCH mode pushbuttons (labeled 4 TO 20, 20 TO 300, 4 TO 300, and UNFILT), and two harmonic mode buttons (labeled 2ND H and 3RD H). In all six modes the AGC and phase-lock loops will lock on to and track input test tones in the amplitude range −40 to +10dBm and the frequency range 930 to 1030Hz; the AGC and phase-lock loops will then normalize the input signal and suppress the test tone. The CRT MODE buttons select various frequency bands of the normalized input signal for resolution into in-phase and quadrature components with respect to the test tone (in the four VECTOR NOTCH modes), the second harmonic of the test tone (in the 2ND H mode), or the third harmonic of the test tone (in the 3RD H mode). In the absence of a patch into the XY IN jack (see Par. 2-17), the display circuits will present the resolved in-phase and quadrature components as proportional vertical and horizontal deflections, respectively, on the CRT, for visual demodulation by the operator. The signals selected by the CRT MODE buttons for resolution and display are as follows:

a. 4 TO 20. The normalized notched noise (NNN) in the bands 4 to 20Hz below and above the test tone.

b. 20 TO 300. The normalized notched noise in the bands 20 to 300Hz below and above the test tone.

c. 4 TO 300. The normalized notched noise in the bands 4 to 300Hz below and above the test tone.

d. UNFILTered. The normalized notched noise in the band from 20Hz to 3500Hz (except for a ±4Hz notch about the test tone and the 200Hz high pass filter at the unit's input).

e. 2ND H. The normalized components of the input signal within ±3Hz of the second harmonic of the test tone.

f. 3RD H. The normalized components of the input signal within ±3Hz of the third harmonic of the test tone.

2-15. SCALE MULT Pushbuttons. The CRT display sensitivity is determined by the five SCALE MULT pushbuttons. Each button is labeled with the factor that the horizontal and vertical scales must be multiplied by, and with the number of dB that must be added to or subtracted from the polar scale, when that button is depressed. The corresponding HOR/VERT and polar dB scale modifiers selected by the SCALE MULT pushbuttons are as follows:

HOR/VERT	X0.5	X1	X2	X5	X10
Polar dB	−20	−14	−8	0	+6

The following paragraphs show how the SCALE MULT buttons change the values read on the horizontal, vertical, and polar scales.

a. The horizontal scale on the graticule is numbered ±(1, 2, 3), and the vertical scale is numbered ±(2, 4, 6). The horizontal scale represents angular degrees, and the vertical scale represents percent change. Although the horizontal and vertical scales represent different units, the same SCALE MULT switch HOR/VERT multiplication factors apply to both simultaneously, as shown in the table below.

SCALE MULT HOR/VERT Settings

		X0.5	X1	X2	X5	X10
Horizontal	1	0.5	1	2	5	10
	2	1.0	2	4	10	20
	3	1.5	3	6	15	30
Vertical	2	1	2	4	10	20
	4	2	4	8	20	40
	6	3	6	12	30	60

b. Phenomena such as gain hits and gain steps are displayed as vertical deflections in percent, but are customarily referred to in dB relative to the tone amplitude. Figure 2-3 is a plot of the relationship between percent change and dB change.

c. The graticule circles used for the polar dB scales are numbered −10, −12, −14, −16, −20, from the outside in. The innermost (−30dB) circle is not numbered. Since the calibrations of the circles represent dB relative to the dB setting of the SCALE MULT switch, the dB value at each setting of the SCALE MULT SWITCH must be added algebraically to the graticule circle values. The following table shows how the dB setting and the graticule reading are added to give the total level in dB of any deflecton:

SCALE MULT dB Setting

		−20	−14	−8	0	+6
Graticule Reading	−30	−50	−44	−38	−30	−24
	−20	−40	−34	−28	−20	−14
	−16	−36	−30	−24	−16	−10
	−14	−34	−28	−22	−14	− 8
	−12	−32	−26	−20	−12	− 6
	−10	−30	−24	−18	−10	− 4

2-16. The SINGLE AXIS switch is a three-position toggle switch with spring return to the center position from either the upper (VERT) or lower (HOR) positions. In the center position, the horizontal signal is fed to the CRT horizontal amplifier and the vertical signal is fed to the CRT vertical amplifier, so that the CRT spot can be deflected over the entire screen. In the VERT position, the input to the horizontal amplifier is grounded so that only vertical deflection is possible. This aids measurement of amplitude jitter on the CRT in the VECTOR NOTCH modes. In the HOR position, the input to the vertical preamplifier is grounded so that only horizontal deflection is possible. This aids measurement of phase jitter on the CRT in the VECTOR NOTCH modes.

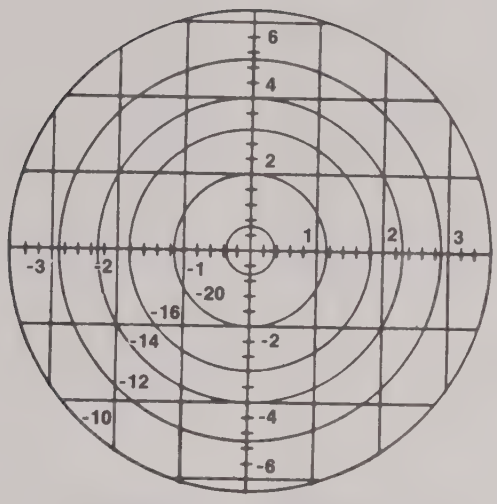


FIGURE 2-2 GRATICULE

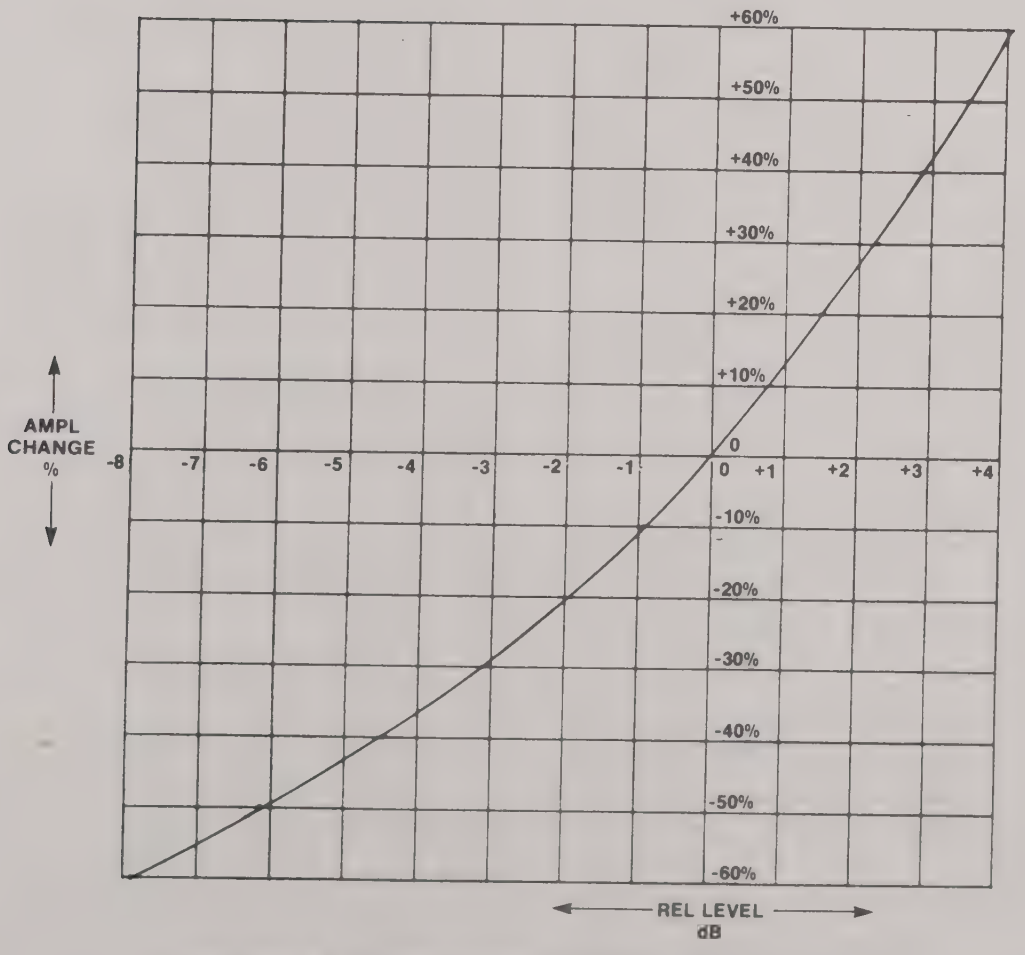


FIGURE 2-3 CONVERSION FROM PERCENT TO dB

2-17. The XY IN Jack is a transfer jack that permits the PB-1C-D to be used as an X-Y oscilloscope or 'vectorscope' to display modem 'eye patterns', 'constellation patterns', or 'decision spaces'. Many modems have X-Y outputs for this purpose.

a. When the XY IN jack is not used, the outputs of the phasor domain circuits (which are derived from the received signal at the INPUT jack) are fed to the inputs of the CRT vertical and horizontal deflection amplifiers.

b. When a patch cord is plugged into the XY IN jack the outputs of the phasor domain circuits are disconnected from the inputs of the CRT deflection amplifiers, the patch cord tip is connected to the input of the horizontal (or X) deflection amplifier, the patch cord ring is connected to the input of the vertical (or Y) deflection amplifier, and the patch cord sleeve is connected to the PB-1C-D ground. The CRT display is then that of an X-Y oscilloscope or vectorscope. Both X and Y inputs have the same nominal deflection sensitivities, which are related to the SCALE MULT switch settings as follows:

SCALE MULT switch setting	X0.5	X1	X2	X5	X10
X,Y IN sensitivities, mV/cm	40	80	160	400	800

c. Since both the X and Y inputs are single-ended, it is necessary to interconnect the grounds of the PB-1C-D and of the source at the other end of the patch cord. The XY IN jack sleeve is connected to the PB-1C-D ground; if the source jack sleeve is connected to the source ground, it is merely necessary to interconnect the two sleeves (i.e., through the third wire of a three-wire patch cord). However if the PB-1C-D and the source are connected to the same power line ground, no further ground interconnection is necessary.

2-18. The XY OUT Jack makes available for external recording the voltages at the inputs of the CRT vertical and horizontal deflection amplifiers. The tip voltage is that at the input to the horizontal deflection amplifier, and the ring voltage is that at the input to the vertical deflection amplifier. The amplitudes of these voltages are not affected by the settings of the SCALE MULT switch.

2-19. The HARMONIC SEPARATION pushbutton is enabled only in the 2ND H or 3RD H CRT MODE. It causes the separation in dB of the selected harmonic (i.e., the level of that harmonic in dB relative to the level of the input quiet tone) to be displayed on the digital multi-mode meter, if the METER MODE LEVEL, NOISE, or NN SEP button is depressed. If depressed when CRT MODE is not 2ND H or 3RD H, the multi-mode meter is blanked.

2-20. The INTERCONNECT A and B Jacks are intended to be patched to the correspondingly-labeled jacks on the Bradley Telcom 75L/PA Hit Counter/Printer Adapter, as shown in Bulletin 3130 at the end of this instruction book. Since the voltages at the tips and rings of the INTERCONNECT jacks may also be used for other test purposes, they are listed below:

a. INTERCONNECT A Jack

1. The tip voltage is that of the notch phase-lock-loop local oscillator; it is in phase with the input signal and is nominally five volts peak-to-peak when unloaded.

2. The ring voltage is the normalized or AGC'd input signal. When the DO NOT READ indicator is off (indicating a valid input signal, i.e., one within the ranges 930 to 1030Hz and −40 to +10dBm), the INTERCONNECT A unloaded ring voltage is a nominal 3.5 volts peak-to-peak sine wave which is offset 4.5Vdc above ground. When the DO NOT READ indicator is on (indicating an invalid signal), the ring voltage is at nominal ground potential.

b. INTERCONNECT B Jack

1. The tip voltage is normalized notched noise (NNN) or normalized input signal with tone removed. The source impedance is 600 ohms, and the level is relative to a 0dBm input when terminated in 600Ω; i.e., the notched noise level in dBm is its separation from the input level in dB. This is independent of the actual tone input level.

2. The ring voltage is the input signal repeated as a single-ended voltage. This is 3 volts peak-to-peak unloaded, when the input voltage is a 2 volt peak-to-peak sine wave (0dBm).

2-21. Rear Connector

The following jacks are repeated at the indicated pin number of the rear connector:

	Tip	Ring
INPUT	24	25
OUTPUT	4	3

Note: Other pins on the connector are used for automatic test adapters. Do not make connections to any other pins without consulting factory.

2-22. LOUDSPEAKER AND CONTROLS.

a. The SPEAKER MODE switch selects the audio signal to be fed to the loudspeaker. When the switch is set to INPUT the input signal (quiet tone plus impairments) is fed to the speaker; and when the switch is set to NOTCH, the normalized notched noise (input signal minus quiet tone) is fed to the speaker. This acoustic output is a valuable aid in identifying certain types of impairments by means of their characteristic 'signatures'. A center-off position permits disconnecting the speaker circuit so that the acoustic output can be eliminated without changing the setting of the SPEAKER VOLUME control.

b. The SPEAKER VOLUME control adjusts the loudness of the acoustic output.

2-23. NNE Switch and SCALE CHANGE ON RED FUNCTIONS Indicator. The NNE toggle switch is set to NORMAL except when the input to the PB-1C-D is the output of a remote Bradley Telcom Transparent Line Generators (TLG) (see Bulletin 4110 at the back of this manual). In that case the TLG must be set to a NOISE GAIN of 14dB or X5 to increase the notched noise/tone ratio in its output by that factor, and the PB-1C-D NNE switch must be set to ATTEN, to reduce by the inverse factor (i.e., −14dB or X1/5), the sensitivities of all functions controlled by the red pushbuttons (CRT MODE, NN SEP, AMPL. JITTER, and PHASE JITTER), as well as the notched

noise voltage at the tip of the INTERCONNECT B jack, and the SPEAKER NOTCH MODE acoustic output. For these settings (i.e., 14dB, X5 NOISE GAIN on the TLG, and NNE ATTEN on the PB-1C-D, the CRT scales and the digital multi-mode meter NN SEP, AMPL. JITTER, scales are direct-reading in terms of the disturbances at the input to the remote NNE. This is equivalent to having a disturbanceless or 'transparent' line between the TLG and the PB-1C-D, so that the PB-1C-D appears to be making measurements at the input to the TLG on the other end of the line. To remind the operator of these −14dB or X1/5 scale changes in the NNE ATTEN position, the switch also causes the SCALE CHANGE ON RED FUNCTIONS indicator to flash.

2-24. Rack Adapter Kit. A rack adapter kit is furnished for mounting the PB-1C-D in a standard 19″ relay rack. The kit comprises two L-shaped adapter brackets and eight 10/32 × 5/16 flat head (undercut) machine screws. Four countersunk holes in each bracket mate four 10-32 tapped holes in each side wall of the PB-1C-D case. The brackets are fastened to the side wall using the machine screws. The PB-1C-D will fit into a 5-1/4″ high rack slot if the feet and tilt-stand are removed. The feet are fastened to the case with 6-32 binding head screws and they may be removed by removing the screws. If the feet are replaced at some future time, each front foot (which also supports the tilt-stand) is mounted with two 1/2″ long screws and each rear foot with one 3/8″ long screw. Adapters for 23″ telephone racks are also available, on special order.

Bulletin 2010

Technical Bulletin

SUPPRESSED TONE PHASOR DOMAIN MEASUREMENT

SUMMARY

A new measurement technique is described for examining a sinusoidal signal. The sinusoid itself is suppressed. The remaining signal components are normalized relative to the tone and are classified in the phasor domain, either relative to the tone, or relative to its harmonics. The result is a remarkable informative real time visual demodulation of the disturbances of the sinusoid. The technique is generally applicable but it is described relative to a telephone transmission channel instrument which is its first application. In this application both go/no-go facility testing for modem compatability, and in-depth diagnostic examination for facility evaluation, are carried out by the same instrument. This derives from the fact that the visually demodulated tone impairments are displayed in the same way that those same impairments are electronically demodulated by the modem receiver, or are as they are superimposed on the tone by the facility.

Frank Bradley 8/15/76

TABLE OF CONTENTS

		PAGE
1.	INTRODUCTION	1
2.	TESTING OF VOICE AND DATA TRANSMISSION FACILITIES	1
3.	CLASSIFICATION OF LINE DISTURBANCES	2
4.	TONE-CORRELATED AMPLITUDE DISTURBANCES	2
5.	TONE-CORRELATED PHASE DISTURBANCES	2
6.	NONSYNCHRONOUS OR UNCORRELATED DISTURBANCES	4
7.	SUPPRESSED-TONE PHASOR DOMAIN, BACKGROUND	4
8.	THEORY OF OPERATION	5
9.	VECTOR NOTCH MODE FACILITY ANALYSIS	7
10.	DISTORTION ANALYSIS, UNFILTERED VECTOR NOTCH MODE	10
11.	DISTORTION ANALYSIS, HARMONIC MODES	10
12.	PHASE INTERCEPT DISTORTION	10
13.	IMPLICATIONS OF THE SUPPRESSED-TONE PHASOR DISPLAY TECHNIQUE	12
	a. LIMITATIONS OF EXISTING PRACTICE	12
	b. NOTCHED NOISE, AN EXAMPLE	12
	c. NEW INFORMATION	13
14.	DISCUSSION OF ACCURACY	14
15.	NON-STANDARD APPLICATIONS	15
	a. GO/NO-GO EVALUATION OF LINE-MODEM COMPATIBILITY	15
	b. EVALUATING DUAL DIAL BACKUP LINES	16
	c. TRACKING NOTCH-FILTER FOR OTHER INSTRUMENTS	16
	d. CHECKING QUALITY OF TEST-TONE SOURCES	17
	e. IDENTIFICATION OF FACILITIES BY SIGNATURES	17

1. INTRODUCTION

The major thrust for the improvement of telecommunication instrumentation derives from the need:

1. To quickly "clear" a facility in the case of a complaint which is not valid.
2. To quickly "tag" a facility in the case of a complaint which is valid.
3. To identify the nature of the impairment for facility maintenance personnel who are trying to clear troubles.
4. To classify facilities in a go/no-go way relative to modem requirements for data-concerned personnel.

These functions appear to be well served by the suppressed-tone phasor domain approach. In this approach the impairments induced by the facility on a test tone are visually demodulated and displayed in real time. Impairments are thereby distinguished with a resolution which is unique. Because of the excellent delineation of the presentation, a meaningful examination of the entire voice band can be carried out at one time and on one display. The present instrumentation (PB-1) thus not only provides results extremely quickly, but it is the only existing hardware which can positively "clear" a facility against suspicion of all the dynamic impairments, including those which have been defined and are now measured by conventional equipment, and those which have not yet been defined. This occurs because the impairment examination is not limited by a set of rules for detection and time averaging as required to produce a numerical display. As a corollary, the instrument does not become obsolete from time to time as new impairments are discovered or rules changed.

Because it examines a facility in the same real time way that modems use that facility, it provides a direct comparison of facility performance vis a vis modem requirements. The same instrument provides valid go/no-go screening capability for relatively unskilled personnel and deep diagnostic information for the more sophisticated user. There is a desirable side benefit, users of the PB-1, at whatever level, develop better insight into the nature of impairments.

An interesting aspect of the technique is elicited by the question "Just what is it that is being measured?" This is most frequently asked when the PB-1 is monitoring a quiet line, because nothing much seems to be happening. The answer is "Everything," i.e., all dynamic impairments. The absence of activity denotes a highly desirable condition because the display not only indicates what impairments are present, but *what impairments are not present*. Usually one or two parameters will predominate, depending upon the type of facility, and their magnitude can be measured. Of equal or greater importance is the information, implicit in the display, that everything else is negligible.

2. TESTING OF VOICE AND DATA TRANSMISSION FACILITIEES

The telephone network was designed primarily to route and transmit voice communications. The performance characteristics of the voice-frequency channels of the telephone

Figure 1 Suppressed Tone Phase Domain Instrument

network are therefore not optimized for transmission of digital data. As a result, problems frequently arise in the transmission of data over the telephone network, and those problems increase greatly with the rate of data transmission. When subscribers use data sets or 'modems' supplied by common carriers, to transmit and receive data over common carrier telephone facilities, the major responsibility for solving any data transmission problems is obviously that of the carriers. However, when subscribers use modems not supplied by common carriers, to transmit data over common carrier telephone facilities, the responsibilities for data transmission problems may not be so clear. Such problems may arise because of deficiencies in the modems, in the facilities, or in both. It then becomes desireable for both subscribers and common carriers to be able to test the telephone network facilities, in order to determine the sources of problems. Such testing must be made not only against voice transmission criteria, but also against data transmission criteria.

Telephone network transmission channels perform differently when loaded and when idle. Since only channels loaded with data can induce disturbances on that data, they are preferably tested in the loaded condition. One method of loading a channel for testing is to transmit a 'holding'

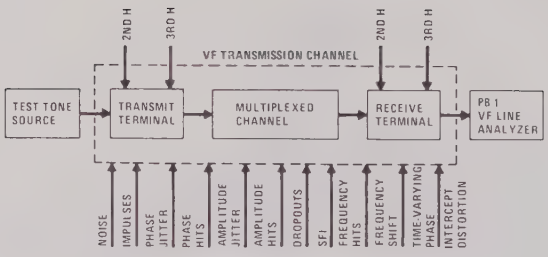


Figure 2 One-Way Facility Testing

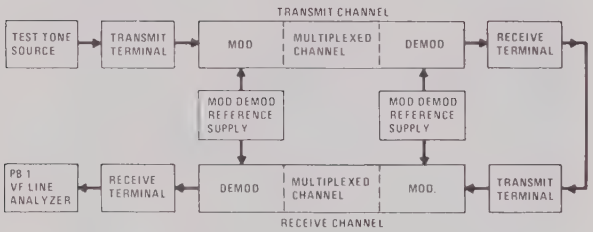


Figure 3 Loopback Facility Testing

tone through that channel. The Model PB-1 VF Line Analyzer, see Figure 1, utilizes such tones as test tones. This instrument, which is the first embodiment of the suppressed-tone phasor domain measurement technique, monitors the tone (i.e., after transmission through channels under test) for disturbances induced on that tone by channel impairments. Figure 2 shows the basic configuration for one-way testing of a telephone transmission facility, and Figure 3 shows the configuration for loopback testing. Various types of disturbances that can be induced on a test tone are shown in Figure 2. Harmonic distortion is introduced only at the terminals because harmonics occurring after the channel has been multiplexed will fall out of band. Although not shown in Figure 3, the disturbances shown in Figure 2 can be introduced into both the transmit and receive channels of a loopback connection. One-way testing detects disturbances in one direction, and loopback testing detects the sum of the disturbances in both directions. In loopback testing, some disturbances may be introduced equally and oppositely in each direction, and thus cancel out, e.g., reference supply problems. Thus, though loopback testing may be more convenient, the results of such testing should be confirmed if possible, by one-way testing in at least one of the two directions, to ascertain that there are no significant one-way impairments that have been canceled out by looping back.

3. CLASSIFICATION OF LINE DISTURBANCES

The test tone, cos wt, as received via the communication channel has disturbances which are synchronous with the test tone and disturbances which are not. This is reflected by the expression below in which g(t) and p(t) are respectively disturbances on the amplitude and phase of the received tone, and $H_k \cos(kwt + \Phi_{kw})$ is the harmonic distortion where k assumes integral values of 2 and over. N(t) are disturbances which are not correlated with, or synchronous with, the received tone.

$$\text{Received tone } V_r = A_w \left[1 + g(t)\right] \cos(wt + p(t)) + N(t) + H_k \cos(kwt + \Phi_{kw})$$

Note that the reference in this discussion is the received tone $A_w \cos wt$. This takes no account of the channel phase shift, frequency shift, or echo. It does consider the difference in phase shift between the tone and its harmonics, Φ_{kw}, a matter of considerable significance, see below.

4. TONE-CORRELATED AMPLITUDE DISTURBANCES (See Figure 4)

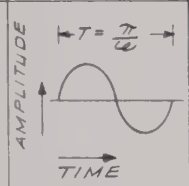
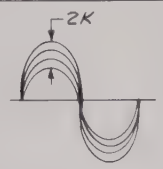
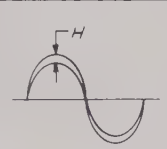
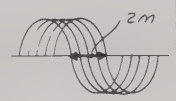
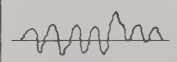
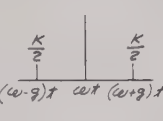
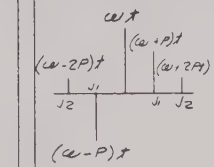
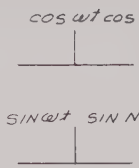
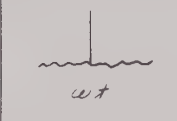
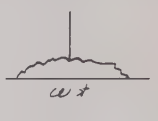
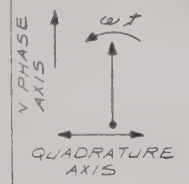
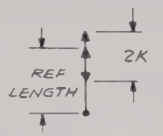
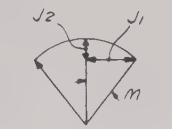
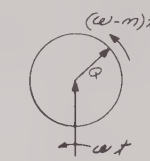
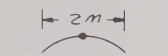
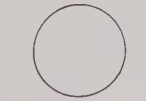
The correlated disturbances which affect tone amplitude are incidental amplitude modulation, amplitude hits, amplitude steps, and dropouts. g(t) is that function of time which describes the amplitude variation of the test tone. It involves a relatively steady state component having a zero time average over the measurement bandwidth of the test instrument. This is "amplitude modulation".* g(t) also has a discontinuous component having a non-zero short time average. This component is called an amplitude hit or amplitude step. An amplitude step is a positive or negative step in g(t). It is measured with respect to the recent average level of the test tone subject to certain rise time and amplitude criteria. An amplitude hit is bi-directional, i.e., a step to a new value and then a return to more or less the original value. A dropout is a large decrease in level or short term loss of signal measured with respect to the received tone level at the time a test is started or other appropriate reference level. Note the difference between a dropout and a gain hit. The latter is defined with respect to a recent average level of the received tone, also there is no rise time criterion for a dropout, merely a level threshold and a minimum duration. The recently promulgated Bell System definition for a dropout is "a reduction in the received tone voltage level by more than 12 dB with respect to its value at the start of the test, which level stays below this threshold for 4 milliseconds or more". In suppressed phasor representation, amplitude jitter appears as a vertical line. Its length is a measure of the magnitude of the jitter. Hits appear as transient vertical excursions, either uni-directional or bi-directional dependent on their time history. The AGC tracking loop of the PB-1 suppresses transient excursions in the long term, but it does not do so instantaneously, otherwise both jitter and hits would be masked. Rather it tracks transient with a time constant of nominally 50 milliseconds so that recovery from a step transient is relatively complete within 1/7 second.

5. TONE-CORRELATED PHASE DISTURBANCES (See Figure 5)

p(t) is that function of time which describes the short term phase variation. It involves a relatively steady state component having a zero time average over the instrumentation

*Amplitude jitter is the sum of the effect of Incidental Amplitude Modulation and noise within the jitter filter bandwidth on the signal amplitude.

Figure 4 Figure 5 Figure 6

		TONE-CORRELATED AMPLITUDE DISTURBANCES		TONE-CORRELATED PHASE DISTURBANCES		TONE-UNCORRELATED DISTURBANCES		
		A	B	C	D	E	F	G
METHOD OF REPRESENTATION	TONE	AMPLITUDE MODULATION	GAIN HIT OR GAIN STEP	PHASE MODULATION	PHASE HIT OR PHASE STEP	SINGLE FREQ INTERFERENCE	NOISE	IMPULSE
MATHEMATICAL	$\cos \omega t$	$(1+K \cos gt) \cos \omega t$	$(1+H) \cos \omega t$	$\cos(\omega t + m \cos pt)$	$\cos(\omega t + N)$	$\cos \omega t + Q \cos mt$	$\cos \omega t + n(t)$	$\cos \omega t + I(t)$
TIME DOMAIN						SFI ONLY TONE NOT SHOWN	 NOISE ONLY TONE NOT SHOWN	IMPULSE ONLY TONE NOT SHOWN
FREQUENCY DOMAIN								
PHASOR								
SUPPRESSED PHASOR ONLY THE DISTURBANCE IN THE PHASOR PLANE IS DISPLAYED. THE REF TONE IS SUPPRESSED	ORIGIN							

bandwidth (typically 20-300 Hz). This is called phase modulation.** Note in Figure 5 that the first sidebands of the modulated tone have an opposite sense as compared to the sidebands of an amplitude modulated tone, and that the second sidebands are AM-like sidebands. This can best be understood by considering the phasor representation. The phasor is rotated plus and minus with respect to reference. This produces a quadrature component between the reference tone and the received tone of amplitude sin Φ. It produces an amplitude variation of (1-cos Φ). The amplitude variation occurs at a double frequency; that is, as the phasor rotates from zero positively and back to zero, the amplitude goes through a complete cycle. And likewise, as the phasor rotates from zero negatively back to zero, the amplitude goes through a complete cycle. The complete mathematical expansion for a single frequency of phase jitter involves an infinite series of Bessel functions, of which the first sidebands correspond to J1 and the second sidebands correspond to J2. For the normally encountered phase modulation, the first two sidebands provide a sufficiently accurate description because of the low index of the modulation.

The Phase Hit column of Figure 5 represents before and after snapshots. It is necessary, in the frequency domain representation, to consider separately the sin wt and cost wt components of the frequency spectrum. Before the phase hit, the signal energy resides in the cos wt spectrum, and the sin wt spectrum is zero. The hit amounts to transfer of energy from the cosine to the sine spectrum. Note that for a true phase hit, the rms sum of the sine and cosine spectrums remains constant. There is no reference phase in a communication channel, thus there is no phase equivalent to a dropout. The test instrument tracks the phase of the received tone more or less slowly, and a phase hit is defined as an abrupt change with respect to the recent average phase of the received tone. Again, criteria are needed to define both the rate of change and the amplitude of the hit. Both steps (unidirectional abrupt changes in phase) and hits (phase discontinuities which are followed by a return to the starting phase) are found on typical common carrier facilities.

In suppressed phasor representation phase modulation appears as a circle arc or as a horizontal line depending upon its frequency. If the display filter passes the second sideband the result will be a circle arc, if the modulation frequency is high enough so that the second sideband is outside the filter pass band, the display will be a horizontal line. Hits produce transient excursions which, depending upon hit transition time, are essentially circle chords aimed at the hit angle. The transients are eventually suppressed by the phase lock loop which, as does the AGC loop, corrects for a step transient in nominally 1/7 second.

6. NONSYNCHRONOUS OR UNCORRELATED DISTURBANCES

Nonsynchronous disturbances are single frequency interference (SF1), steady noise, and impulse noise. Quantizing, aliasing, and sampling interval noise in PCM systems is a special case of correlated noise which previously has been lumped with random noise. With the suppressed phasor technique such noise has a characteristic pattern. Figure 6 shows a single frequency interfering tone, which, when added to the test tone, produces a phasor domain signal as shown. There is a unit length vector directly upward representing cos wt, plus the additive SF1 vector spinning around the tip of the unit vector. The amplitude of this spinning vector is the amplitude of the single frequency interfering tone relative to the tone amplitude, and the circular frequency of its rotation is the difference frequency between the test tone cost wt and the single frequency interfering tone. It is, in effect, a single sideband modulation.

Steady noise is similar to single frequency interference except that it comprises a spectral distribution of varying amplitude interfering signals. As also depicted in Figure 6, a phasor representation, there is no single, unique spinning additive vector. The instantaneous value of the output can be any place within the relatively jagged circle. The amplitude of the "circle" is a measure of the summation of the noise factors as they reinforce and interfere with each other.

Figure 6 also shows an impulse. Impulses are highly variable and usually brief, lasting only a few milliseconds. A typical signal to steady noise objective is 24 dB. A comparable signal to impulse noise objective is 5 dB. The difference is acceptable partly because of the short duration of impulse noise, and partly because hit ratios are based on rms/peak, whereas steady ratios are rms/rms. Figure 6 represents the instantaneous situation during the impulse which will typically have its energy in some band that is not necessarily symmetric about the tone, and which will not necessarily define a circle in the phasor diagram.

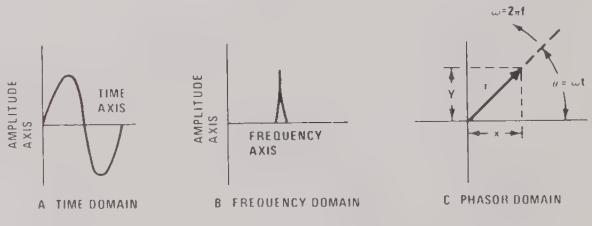


Figure 7 Representations of a Sinusoidal Tone in Three Domains

7. SUPPRESSED-TONE PHASOR DOMAIN, BACKGROUND

Suppressed-tone phasor-domain representation is a new technique for rapid display, classification, identification, and measurement of all disturbances induced on a test tone by a transmission channel.

Signals are conventionally represented in the time domain (Figure 7A), as displayed by oscilloscopes, and in the frequency domain (Figure 7B), as displayed by spectrum analyzers. Signals may also be represented in the phasor domain, and displayed on suitable instruments, such as the PB-1 VF Line Analyzer, Figure 1.

*Phase jitter is the sum of the effect of Incidental Phase Modulation and of noise within the jitter filter bandwidth on the signal phase.

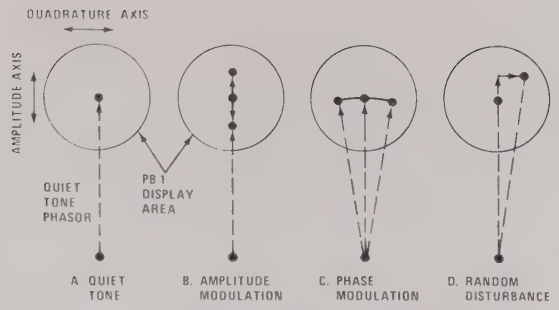


Figure 8 Suppressed-Tone Phasor Representation

In the phasor domain, a sinusoid of frequency f(Hz) is represented by a radius vector called a phasor, which hypothetically rotates about its origin at the angular velocity $w(=2\pi f)$ radians per second (Figure 7C), but which appears stationary because it is illuminated at exactly the same position in each rotation by a hypothetical stroboscope. The amplitude of the sinusoid is represented by the length of the phasor, and the phase of the sinusoid is represented by the angular position of the phasor at the instant of 'illumination'. One common 0° angle reference for phasors is the horizontal to the right of the origin (Figure 7C); another, used by the PB-1, is the vertical up from the origin (Figure 8A). Note that phasors may be represented either by the polar coordinates r(length) and θ (angle) with respect to the 0° reference, or by the rectangular coordinates which represent the projections or 'shadows' of the phasor on the in-phase axis and on the quadrature axis respectively. These shadows describe the familiar time-domain sine wave. As the phasor rotates through 360°, the sine (or cosine) wave goes through a complete cycle. When a pure sinusoidal test tone is transmitted through a voice-frequency communication channel, impairments in the channel may induce on that tone a wide range of disturbances such as noise, phase modulation, amplitude modulation, interfering tones, harmonics resulting from nonlinear distortion, and transients of various kinds. If the steady-state component of the received signal (i.e., the 'quiet tone') is displayed as a vertical phasor (Figure 8A), the disturbances (which are not stationary with respect to the tone) will add (vectorially, and on an instantaneous basis) to the tip of that phasor. The entire phasor need not be shown, because its coordinates, whether polar or rectangular, are completely defined by a point representing the location of its tip with respect to the reference axes. Since disturbances are usually much smaller in amplitude than the test tone, the tip of the resultant phasor (representing the vector sum of the steady-state received tone plus instantaneous disturbances) is normally confined to a small area around the tip of the steady-state tone phasor. This is the area that is displayed by the PB-1 in its vector mode. By suppressing the steady-state tone phasor (which contains no information about disturbances) so that the tip of that phasor is at the center of the display, only the disturbance phasors are shown. These can therefore be shown on an enlarged scale, thus increasing the resolution and accuracy with which those disturbances can be measured. The direction and amplitude of the disturbance phasors on the suppressed-tone phasor display depend on the nature and amplitude of the disturbances.

8. THEORY OF OPERATION (See Figure 9)

The mechanization employs two high-gain closed loops, an Automatic Gain Control (AGC) loop and a Phase-Lock Loop (PLL), which are interconnected to operate as a narrowband notch filter that automatically tracks and suppresses a steady-state tone. A received signal, comprising a steady-state test tone (V_r cos wt) and accompanying disturbances caused by impairments in the transmission channel under test is amplified by the AGC Amplifier so that the steady-state tone (V_{ref} cos wt) is normalized by being made equal to a reference voltage (V_{ref} cos wt) from the PLL. The normalized steady-state tone and its disturbances (which remain in scale to that tone) are fed to a Difference Amplifier and to the PLL. The PLL locks on to the tone component (V_r cos wt), and develops two orthogonal reference voltages: V_{ref} cos wt, in phase with the steady-state tone; and V_{ref} sin wt, in quadrature with the steady-state tone. The in-phase reference voltage is fed to the Difference Amplifier and to the NNN Cos wt Multiplier. The quadrature reference voltage is fed to the NNN Sin wt Multiplier.

The output of the Difference Amplifier is the normalized input signal with the normalized received tone removed, leaving only the normalized disturbances. Disturbances remaining after a test tone has been removed, suppressed, or 'notched' from a signal, are conventionally called 'notched noise'. Since the PB-1 notches the steady-state tone from the normalized signal, the remaining disturbances will be referred to as 'normalized notched noise' (NNN).

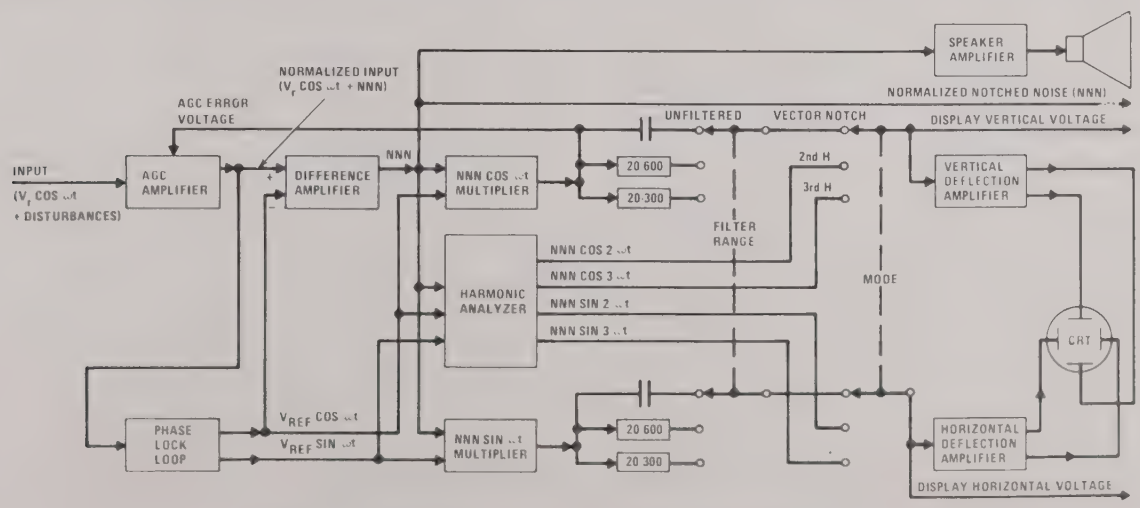


Figure 9 PB-1 VF Line Analyzer, Simplified Block Diagram

In the so-called "VECTOR NOTCH" mode the NNN is classified vectorially, i.e., in the QAM plane, with respect to the test tone. The NNN output of the Difference Amplifier is fed to the NNN Cos wt Multiplier, to the NNN Sin wt Multiplier, and through an amplifier to a loudspeaker. The NNN Cos wt Multiplier output is the NNN component in phase with the steady-state tone; this is fed, through the FILTER RANGE and MODE switches, to the CRT Vertical Deflection Amplifier.

The NNN Sin wt Multiplier output is the NNN quadrature component; this is fed, through the FILTER RANGE and MODE switches, to the CRT Horizontal Deflection Amplifier. Since these components are normalized, the corresponding CRT deflections may be measured against CRT graticule scales calibrated relative to the received test tone. The voltage NNN cos wt is also used as the error voltage that causes the AGC Amplifier to normalize the received signal so that the received tone equals the in-phase reference tone from the PLL.

The time constants of the AGC and Phase-Lock Loops are selected so that the loops operate rapidly enough to recover from transients within the conventional 1/7 second dead time interval of Hit Counters, but do not operate so rapidly that they mask Hits, Steps, or other transients.

The NNN voltage from the Difference Amplifier and the in-phase and quadrature reference voltages from the PLL are fed to a Harmonic Analyzer that develops in-phase second and third harmonic components, and quadrature second and third harmonic components, of the Normalized Notched Noise. In the second harmonic mode, the in-phase second-harmonic component (NNN cos 2wt) is fed to the vertical deflection amplifier, and the quadrature second harmonic component (NNN sin 2wt) is fed to the horizontal deflection amplifier. Similarly, in the third harmonic mode, the in-phase third-harmonic component (NNN cos 3wt) is fed to the vertical deflection amplifier, and the quadrature third harmonic component (NNN sin 3wt) is fed to the horizontal deflection amplifier.

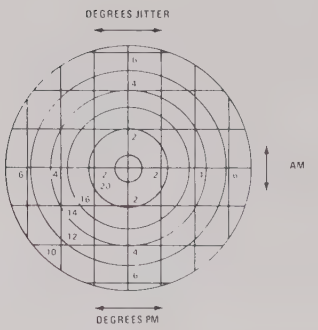


Figure 10 Graticule, Circles Calibrated in Relative dB

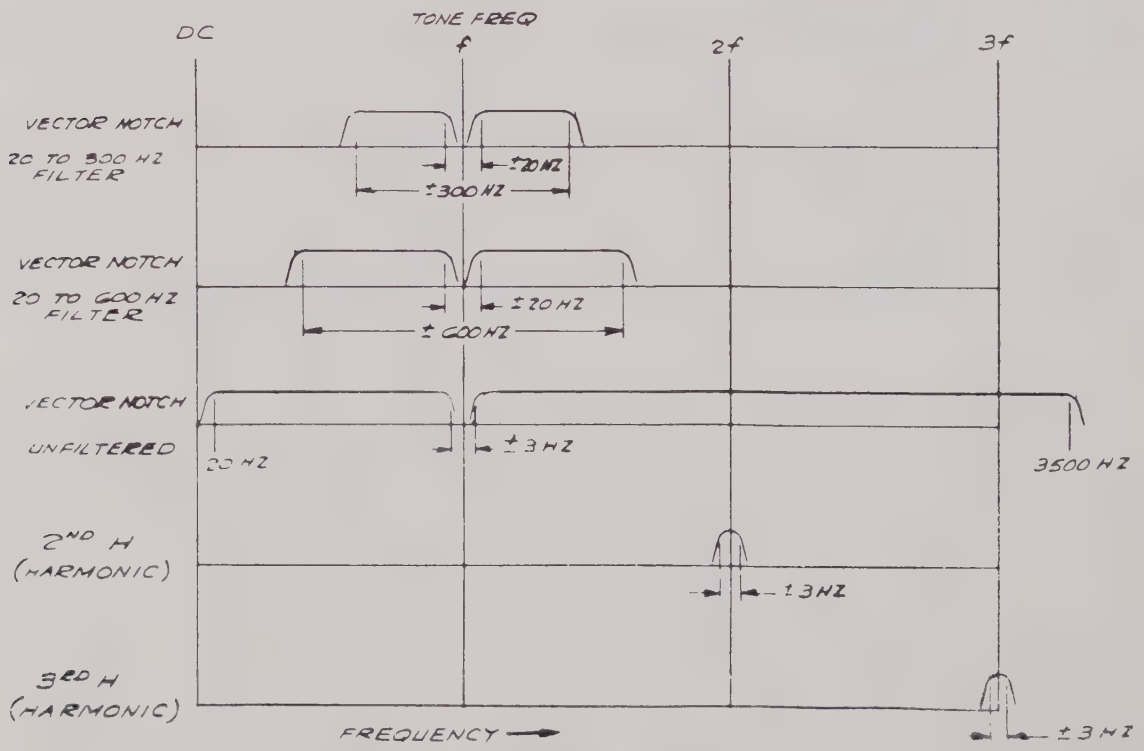


Figure 11 Bandwidth of PB-1 Display in Various Modes

The instantaneous disturbance, as classified in the QAM plane is measured against a graticule which has three scales, Figure 10. The quadrature (horizontal) scale is graduated in degrees of phase jitter. The in-phase (vertical) scale is graduated in % AM, and the polar (circular) scale is calibrated in dB relative to the received tone. Scale Multiplier (or adder for the dB scale) is switch selectable.

The acoustic notched noise output is informative because the tone is attenuated by more than 50 dB and hence does not override the characteristic sounds of the impairments. Harmonics, SFI, tone and modulating tones may be clearly distinguished when they are 50 dB down. Transients too are well delineated. Modulation hits (phase, gain, dropouts) "pull" the tracking loops causing the tone to "leak" through during loop recovery. The result is a sonar-like "ping". Impulse hits do not pull the loops and are therefore audibly reflected as a pop, click, or momentary noise burst. Short duration phase or gain hits also do not have time to pull the loop and so sound like impulse hits but cause excursions at a fixed deflection angle (horizontal or vertical).

That segment of the VF channel bandwidth which is examined in the several operating modes is indicated in Figure 11. The 20 to 300 Hz filter corresponds to the Bell and CCITT jitter filter. The 20 to 600 Hz filter is a frequency apeture which more closely approximates that of synchronous modems (using 1700 Hz as the tone frequency). The unfiltered mode permits examination of the entire voice band. The two harmonic filters are narrow to permit examination of harmonics in the presence of a higher level of background noise.

9. VECTOR NOTCH MODE FACILITY ANALYSIS

Diagnostic and measurement capabilities are illustrated in Figure 12 to 29. All data is obtained using a 1004 Hz test tone at -16 dBm, with the instrument in the vector mode, with the speaker broadcasting with notched noise. The bandwidth of the display is determined by one of three filters, (20-300 Hz), (20-600 Hz0 and UNFILTERED. The left-hand photograph of each pair was taken with the (20-300 Hz) filter, and the right-hand photograph of each pair was taken at UNFILTERED. The (20-300 Hz) filter provides displays compatible with conventional Bell System and CCITT Phase Jitter test sets. However, this filter limits the disturbance bandwidths displayed to those in the sidebands 20 to 300 Hz below the test tone and 20 to 300 Hz above the test tone. In contrast, the UNFILTERED mode provides displays (right-hand photos) showing the entire spectrum of disturbances from 30 to 3500 Hz, with a notch bandwidth so narrow that disturbance components within 1 Hz of the test tone frequency may be observed.

In the detection of modulation impairments, the notched noise is translated downward in frequency by the amount of the test tone and is thus centered at dc with the lower sideband folded back onto the upper sideband. This is accomplished by an internal modulator which multiplies the notch noise by the reference tone. At the same time, the same modulator translates the notched noise upward by the amount of the tone frequency, because the modulator produces the sum as well as the difference frequencies of its two inputs. The dc-centered sidebands produce the 20 to 300 Hz picture, the upper sidebands being eliminated by the filter. The dc-centered plus the double-tone-frequency sidebands produce the UNFILTERED mode picture. Note that modulation impairments show up two ways in the UNFILTERED mode. This is really a reflection of the instrumentation used to reduce them to a display and not a picture of what is actually happening to the tip of the tone factor. It is useful because it 'flags' or calls attention to the modulation impairments, allowing them to be observed even in the presence of a larger amount of noise. The same thing is true in amplitude jitter where the circles are vertically oriented. For Transient modulation impairments, the circles grow or expand to one side or the other depending upon the hit direction and its dynamics. In low frequency modulation phenomena, the circles oscillate back and forth or up and down at the modulation frequency. Figures 12 through 17 show various types of non-tone-correlated disturbances. Figures 18 through 21 show various types of tone-correlated phase disturbances. Figures 22 through 25 show various types of tone-correlated amplitude disturbances.

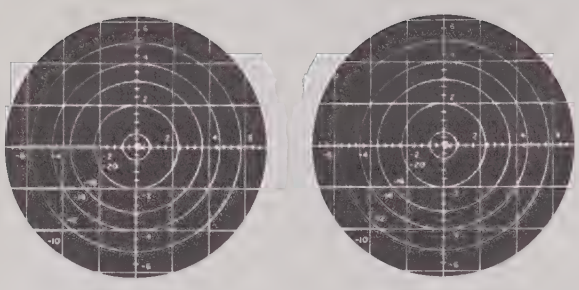


Figure 12

QUIET TONE: All disturbances more than 50 dB below tone level.
Display: Spot at origin (tone phasor tip stationary).
Sound: Inaudible

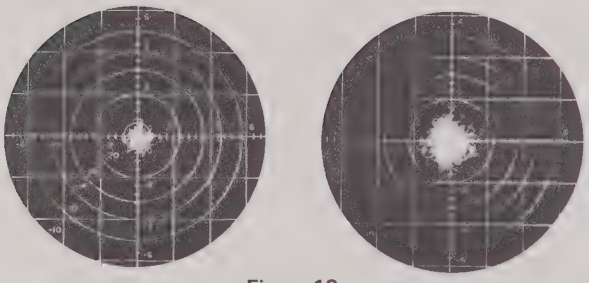


Figure 13

STEADY NOISE: White Noise 25 dB below tone level.
Display: Spot moves in random manner around origin. Note that because of wider bandwidth, the UNFILTERED display passes more noise.
Sound: Steady hiss

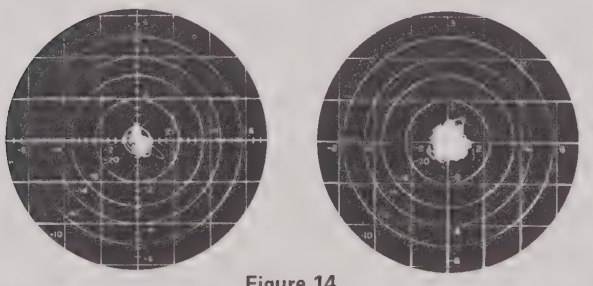


Figure 14

STEADY NOISE PLUS IMPULSE: White Noise 25 dB below tone level, plus single impulse 10 dB below tone level. The impulse shown, which has an 800 to 2,300 Hz flat spectrum, is representative of impulses occurring on VF channels.
Display: Transient deflection at random angle. The steady White Noise typically does not 'modulate' or widen the impulse transient deflection because the impulse is too short to 'pull' the AGC or Phase-Lock Loop. See Phase Hit (Figure 7-4) and Gain Hit (Figure 7-7) for contrast.
Sound: Steady hiss with 'pop' at time of impulse.

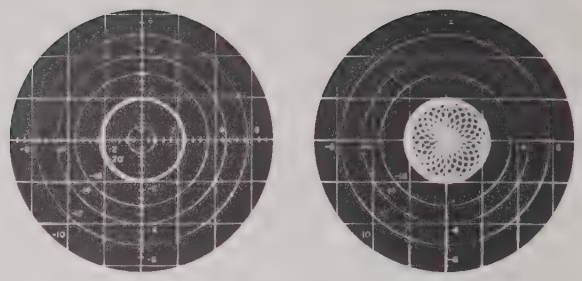


Figure 15

SINGLE-FREQUENCY INTERFERENCE (SFI): 10% SFI (i.e., 20 dB below tone level) at 1100 Hz.
Display: Spot traces circle about origin as SFI phasor spins around tip of tone phasor at difference frequency of 100 Hz (=1100 Hz-1000 Hz). The difference frequency is within the passband of the 20 to 300 Hz filter.
Sound: 1100 Hz tone.

Figure 16

SFI PLUS STEADY NOISE: 10% SFI (20 dB below tone level) at 1100 Hz, plus White Noise 25 dB below tone level.
Display: Characteristic doughnut shape as SFI circular trace is widened by noise.
Sound: Steady hiss plus 1100 Hz tone.

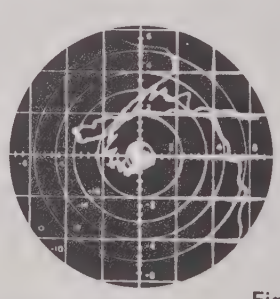


Figure 17

FREQUENCY HIT PLUS STEADY NOISE: White Noise 25 dB below tone level, plus a single 2-Hz Frequency Hit.
Display: Spot deflects and then spirals back toward origin as the Phase Lock Loop acquires and tracks the new frequency. Trace is modulated by the noise.
Sound: Steady hiss with loud tone-frequency 'ping' at time of hit.

Figures 18 through 21 below show various types of tone-correlated phase disturbances

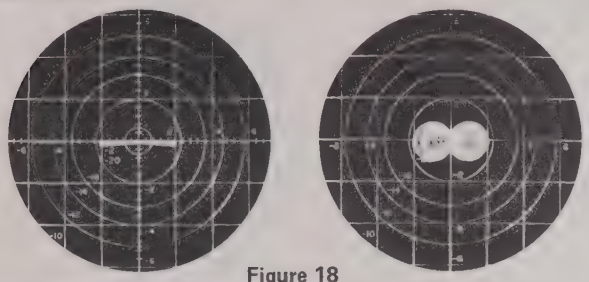


Figure 18

PHASE MODULATION: 10° Phase Modulation at 100 Hz.
Display: Spot traces a nearly horizontal circular arc. Note that the UNFILTERED display passes upper PM sidebands. See comments on Filtered and Unfiltered Displays on Page 6. The diameter of the circles is PM magnitude.
Sound: 900 Hz and 1100 Hz tones (± 100 Hz sidebands of 1000 Hz tone).

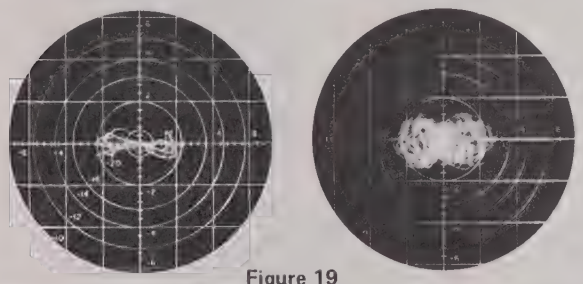


Figure 19

PHASE MODULATION PLUS STEADY NOISE: 10° Phase Modulation at 100 Hz plus White Noise 25 dB below tone level.
Display: Horizontal dispersion exceeds vertical dispersion.
Sound: Steady hiss plus 900 Hz and 1100 Hz tones (± 100 Hz sidebands of 1000 Hz).

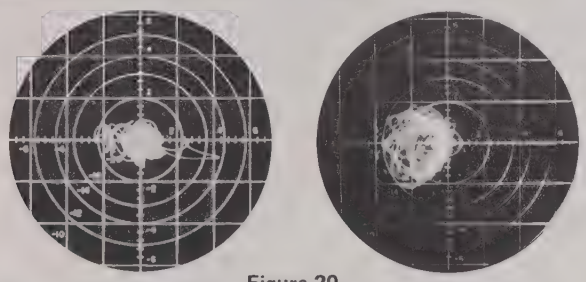


Figure 20

PHASE STEP PLUS STEADY NOISE: 10° Phase Step with 4 millisecond rise time, plus White Noise 25 dB below tone level.
Display: Phase transient causes essentially horizontal deflection of spot. Phase Lock Loop moves to the new phase with a recovery time of 1/7 second. During this recovery time, any noise present on the signal vertically modulates or widens the essentially horizontal transient excursions. The UNFILTERED display shows momentary appearance of a sideways-oriented circle for the duration of hit and the recovery time of the instrument. Its diameter is the hit magnitude.
Sound: Steady hiss with tone-frequency 'ping' at time of hit.

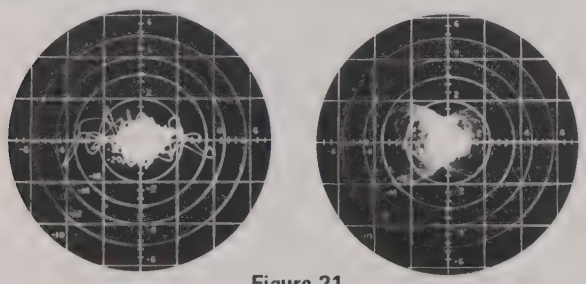


Figure 21

PHASE HIT PLUS STEADY-NOISE: 20° Phase Hit with 4 millisecond rise time and 100 millisecond duration, plus White Noise 25 dB below tone level.
Display: Same as Figure 7-3, except that horizontal excursion is symmetrical about origin. The UNFILTERED display circle alternately appears to the left and right at a rate dependent upon the hit duration and rise time.
Sound: Steady hiss with tone-frequency double 'ping', one at leading edge and one at trailing edge of hit. This double ping can be audibly resolved for Phase Hit durations as short as 40 milliseconds.

Figures 22 through 25 below show various types of tone-correlated amplitude disturbances

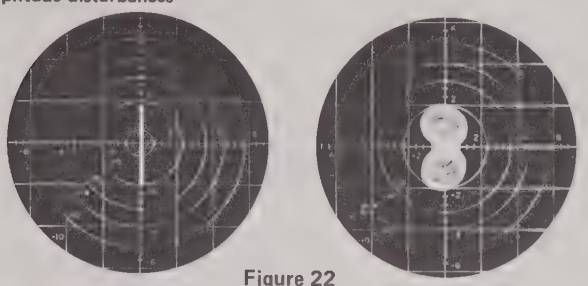


Figure 22

AMPLITUDE MODULATION: 10% AM at 100 Hz.
Display: Spot makes vertical trace symmetrical about origin. The UNFILTERED display passes the upper AM sidebands; see comments on Filtered and Unfiltered Displays on Page 6. The diameter of the circle is the AM.
Sound: 900 Hz and 1100 Hz tones (± 100 Hz sidebands of 1000 Hz tone).

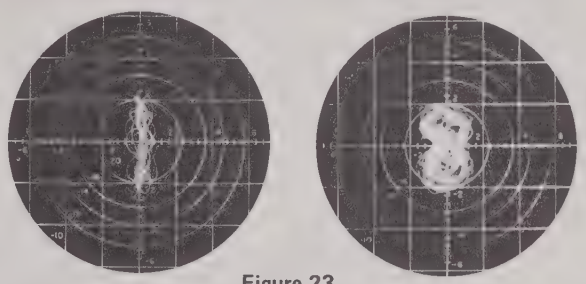


Figure 23

AMPLITUDE MODULATION PLUS STEADY NOISE: 10% AM at 100 Hz, plus White Noise 25 dB below tone level.
Display: Vertical dispersion exceeds horizontal dispersion.
Sound: 900 Hz and 1100 Hz tones (± 100 Hz sidebands of 1000 Hz tone) plus hiss.

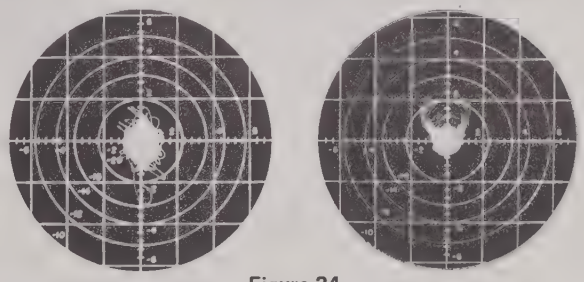


Figure 24

GAIN HIT PLUS STEADY NOISE: 2 dB Gain Hit with 4 millisecond rise time and 100 millisecond duration, plus White Noise 25 dB below tone level.
Display: Amplitude transient causes essentially symmetrical vertical excursion. Depending on size of hit and LEVEL ADJ setting, the DO NOT READ lamp may go on momentarily as the AGC loop moves to new level with a recovery time of 1/7 second. The UNFILTERED display circle alternately appears up and down at a rate dependent upon the duration and rise time of the hit.
Sound: Steady hiss with tone frequency double ping, one at the leading edge and one at the trailing edge of the hit. This double ping can be audibly resolved for hit durations as short as 40 milliseconds.

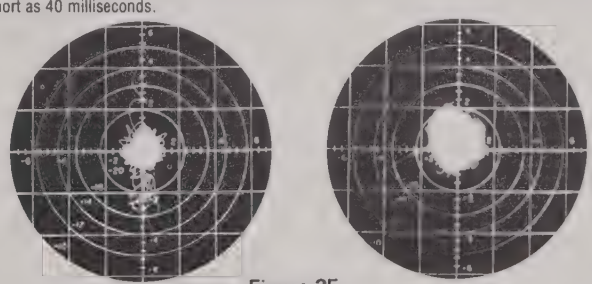


Figure 25

DROPOUT PLUS NOISE: 12dB, 10 millisecond fast dropout plus White Noise 25 dB below tone level.
Display: Deep vertical drop. DO NOT READ lamp goes on and remains on until after end of dropout.
Sound: Noise hiss, with loud, brief tone-frequency 'ping'. As dropouts get shorter, the ping becomes closer to the 'pop' noise of an impulse. At 2 milliseconds dropout duration, the tone component of the noise is barely distinguishable.

Figure 26

Figure 26
SECOND HARMONIC DISTORTION: Second Harmonic Distortion 30 dB below tone level.
Display: Four-lobe cloverleaf pattern, which may rotate continuously in the presence of frequency translation, move through limited angles in the case of low frequency jitter, or expand and contract in the presence of harmonic hits.
Sound: Distinctly audible second harmonic of test tone.

Figure 27
SECOND HARMONIC DISTORTION PLUS NOISE: Second Harmonic Distortion 30 dB below tone level, plus White Noise 30 dB below tone level.
Display: Same as Figure 8-1, with dispersion caused by noise.
Sound: Audible second harmonic of test tone over noise hiss.

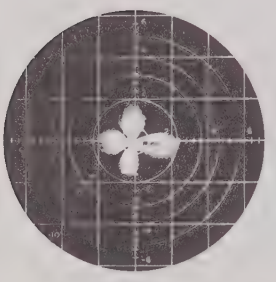


Figure 27

Figure 28
THIRD HARMONIC DISTORTION: Third Harmonic Distortion 30 dB below tone level.
Display: Three-lobe cloverleaf pattern.
Sound: Audible third harmonic of test tone.

Figure 29
THIRD HARMONIC DISTORTION PLUS NOISE PLUS PHASE JITTER: Third Harmonic Distortion 30 dB below tone level, plus White Noise 30 dB below tone level, plus 10° Phase Jitter.
Display: Three-lobe cloverleaf pattern plus noise smear plus phase jitter circle pattern.
Sound: Audible third harmonic of test tone over noise hiss.

Figure 28

Figure 29

10. DISTORTION ANALYSIS, UNFILTERED VECTOR NOTCH MODE

Second and Third Harmonic Distortion are visible in the UNFILTERED vector mode, but (for test tones of 800 Hz and higher) are out of the passband of the 20-300 Hz and 20-600 Hz filters. Figures 26 through 29 are thus for the UNFILTERED vector mode only. Because harmonics of the test tones are coherent with that test tone, they form cloverleaf patterns that indicate the order of the harmonic. Pure second harmonic forms a four-lobe cloverleaf pattern; pure third harmonic forms two nearly coincident three-lobe cloverleaf patterns which is actually a six-lobe pattern folded over.

11. DISTORTION ANALYSIS, HARMONIC MODES

Figure 31 is a typical second harmonic or third harmonic display in the harmonic modes. The deflection amplitude is a measure of the distortion magnitude, and the deflection angle is a measure of the phase intercept distortion of the channel. Since phase intercept distortion is an uncontrolled parameter, the deflection may be in any direction. It is therefore usually convenient to read the deflection against the circular (POLAR dB) scales. In the most sensitive scale position, the inner circle corresponds to a separation of -50 dB; i.e., the harmonic level is 50 dB below the tone level.

Harmonic distortion remains in-band only when it occurs at baseband appearances of the signal. Once a channel has been multiplexed distortion products fall out of band. Figure 30 shows the entry points of harmonic distortion at a VF channel having voice appearances only at each end.

When frequency translation is present, the phase intercept distortion angle changes continuously at a constant rate and the spot moves in a circular path, as shown in Figure 31B. The impairment location causing it is shown in Figure 30. Note that the Receive Terminal, the frequency of the distortion content, cos (2wt + st), differs from twice the frequency of the fundamental, cos 2 (wt + st) by the amount st. This is the equivalent of an SFI input at a beat frequency of st. When an additional second harmonic distortion, K_r cos (2 wt + 2 st) is introduced at the Receive Terminal, after the frequency translation, it is distortion of the received frequency; it is thus exactly double the received frequency and produces a stationary spot. In Figure 31C, note that the circle radius (K_t) corresponds to the distortion which occurs ahead of the frequency translation; the offset (K_t) of the center of the circle corresponds to the distortion which has occurred after the frequency translation; and the rate at which the circle is traversed by the spot is a measure of the frequency translation. The foregoing analysis may be extended to third harmonic distortion.

There may be multiple frequency translation sources as well as other phenomena which cause variations in the phase intercept distortion angle. Phase hits cause intermittent angular motion of the spot. Phase modulation causes oscillatory angular motion of the spot. Filters limit the display bandwidth in the harmonic modes so that only low-frequency jitter can be observed. There may also be harmonic amplitude hits, usually involving PCM carrier, which cause radial motion of the spot. There are normally multiple distortion sources although in a trouble situation, usually one will predominate. These phenomena may occur at any voice appearance in the transmission path, with unpredictable phase shift between their point of generation and the final output. The result is spot motion in random directions. The operational significance of the above is that if the distortion spot displays high mobility it is an indication that the channel will have trouble passing data.

12. PHASE INTERCEPT DISTORTION

The time delay for any frequency component passing through a transmission medium is the slope of the line joining that point on the curve with the origin on a phase vs. frequency plot. One condition required for undistorted trans-

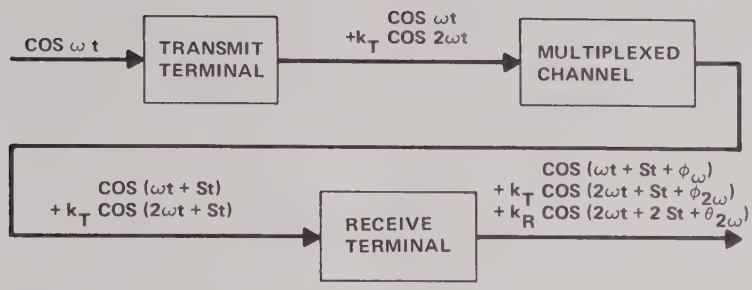

COS ω t
TRANSMIT TERMINAL
COS ωt
+k_T COS 2ωt
MULTIPLEXED CHANNEL
COS (ωt + St)
+ k_T COS (2ωt + St)
RECEIVE TERMINAL
COS (ωt + St + φ_ω)
+ k_T COS (2ωt + St + φ_2ω)
+ k_R COS (2ωt + 2 St + θ_2ω)

Figure 30 Sources of Second Harmonic Distortion (Simplified Analysis)

A B C

Figure 31 Typical Displays in the 2nd H and 3rd H Modes

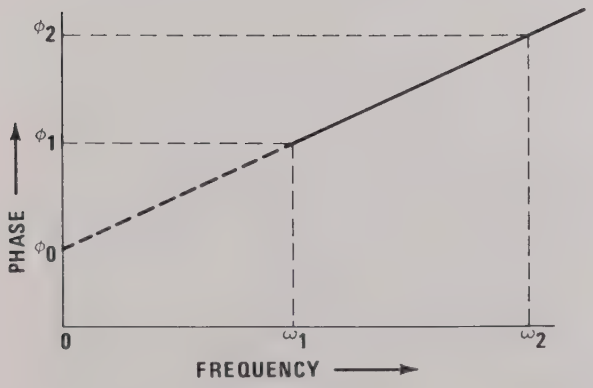


Figure 32 Definition of Phase-Intercept Distortion

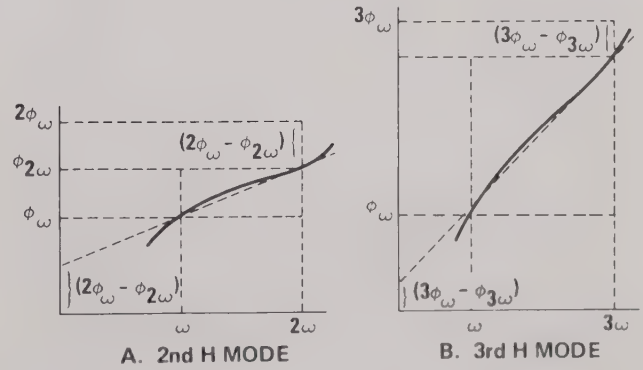


Figure 33 Quantities Measured in 2nd H and 3rd H Modes

mission of a complex wave shape is that the phase vs. frequency curve (plotted in linear units, and extrapolated down to DC) be a straight line passing through the origin. This is the response corresponding to a pure time delay. The slope of this line is the time delay, t. Dimensionally $\Phi/w = t$; Radians/(Rad/Sec) = Sec. There is no time domain wave-shape distortion because all frequency components have the same time delay and therefore arrive in the seme relative phase at the far end as they leave at the near end.

Note that a perfectly linear phase vs. frequency curve (zero envelope delay distortion) is not a sufficient condition for low baseband distortion because (Figure 32) the component of frequency w_1 has a time delay Φ_1/w_1 which is different from that of the w_2 component, Φ_2/w_2. This distortion is a result of the intercept angle Φ_0, of the extrapolated phase vs. frequency curve, at zero frequency. This is known as the phase intercept distortion. It is an uncontrolled parameter in most communications systems.

The angular displacement of the spot for either second or third harmonic distortion measurement is a measure of the phase intercept distortion. In the mechanization of the instrument, the received tone, cos $(wt + \Phi_w)$ is tracked. It is then doubled, i.e., cos $(2wt + 2\Phi_w)$. The phase and amplitude of the second harmonic cos $(2wt + \Phi_{2w})$ is plotted with respect to the double frequency tone as a reference. Referring to Figure 33 which is a phase vs. frequency plot, the phase difference between cos $(2wt + 2\Phi_w)$ and cos $(2wt + \Phi_{2w})$ is $(2\Phi_w - \Phi_{2w})$. This is the deflection angle of the harmonic distortion spot. It is also the phase intercept distortion based on measurement at frequencies w and 2w. A similar observation is true with respect to the third harmonic.

Angular motion of the harmonic spot corresponds to changes in phase intercept distortion. This motion will always be along an arc of some circle for a given distortion source and the phase intercept distortion due to that source. However, a multiplicity of distortion sources may exist in a transmission channel relative to a multiplicity of phase intercept distortion sources. The case of frequency translation described above is commonly encountered.

The frequency response of this measurement in the mechanization is limited by the filter bandwidth in the deflection amplifier. This must be narrow to keep the erratic spot motion induced by background noise below acceptable limits relative to the lowest harmonic distortion measurement threshold (50 dB below signal level). Where it is desired to study the phase intercept distortion, a harmonically rich signal can be transmitted. This raises the harmonic level well above the normal noise level and permits the filter bandwidth to be increased.

13. IMPLICATIONS OF THE SUPPRESSED-TONE PHASOR-DISPLAY TECHNIQUE

The single most significant fact about the suppressed-tone phasor-display technique is that it permits a meaningful display of all impairments over a wide VF spectral range at one time. Such a presentation in the time domain or the frequency domain is not meaningful because the information is not comprehensible. Early users of the PB-1, primarily Bell System DATEC engineers, were quick to notice that, using it as the translating device between facility and craftsman, not only do relationships between presently defined impairments become clear, but previously unobserved impairments become apparent. Impairments are shown in real time as they actually happen, so that it is possible to characterize a facility in a matter of minutes. In the VECTOR NOTCH, UNFILTERED mode, the display includes the entire voice band, except for the notch region within ± 1 Hz of the test tone. The information is classified in the QAM plane, a classification which shows phase relationships between impairments and tone more clearly than any other measurement or display technique. Phase relationship information pinpoints fault location in a facility because it permits noise, modulation, and harmonic distortion disturbances to be resolved by inspection. As a result, the instrument has quickly become a 'microscope' for the examination of facility performance from an entirely new and informative viewpoint.

a. LIMITATIONS OF EXISTING PRACTICE

Conventional transmission channel instrumentation reduces tone impairments to sets of numbers. To accomplish this the impairments are filtered, detected by one of a variety of detectors, e.g., average value, rms, quasi-rms, peak, etc., time averaged, and displayed as a numerical result. Transient phenomena are also monitored in this pattern. The time-averaging interval typically becomes 15 minutes, and the detector a presetable analog threshold level detector with artfully defined criteria for hit duration, hit rise time, and hit interval. The problems with such measurements are as follows:

1. It is virtually impossible to convert two-dimensional time-varying and/or random quantities into a set of numbers of any reasonable set size. Information is necessarily lost in the process. The present 12 to 16 number set of line parameter readings falls short of describing all line conditions. Moreover, "comprehension" of this set of numbers, in the sense of fully integrating their meaning, requires a sophistication which is rare at craft level.

2. Any set of rules for converting the information into numbers, no matter how artfully chosen, can represent only what is generally the case for known phenomena. Exceptional cases and unrecognized impairments are frequently hidden. It is accepted that the results will be misleading in some small percentage of cases. Nevertheless exceptions and 'new' impairments always come as a surprise, and they result in those occasional long-duration and costly maintenance efforts which continue interminably until someone recognizes the hole in the definition through which the impairment has slipped.

3. A costly characteristic of the presentation of purely numerical results is obsolescence. From time to time new impairments are defined. Further the classification rules for existing impairments are changed, as a result of new data set requirements, new tariffs, new facilities, and/or discovery of new phenomena. When this happens, existing test equipment, which mechanizes existing rules, becomes obsolete. The PB-1, in its unfiltered vector mode, imposes virtually no limitations on the impairments displayed. The rules are "in the eye of the beholder".

b. NOTCHED NOISE, AN EXAMPLE

As an example of the effect of instrument mechanization rules on information content, consider C-message-weighted notched noise. Notched noise is what remains after the tone is removed. It includes additive noise, modulation impairments, and harmonic distortion impairments. Because it includes all disturbances, notched noise is the single most meaningful conventional existing impairment parameter for evaluation of facility/modem compatibility. This has been recognized in the Bell System

"D" tariff, which essentially specified rms notched noise and nonlinear distortion.

RMS noise is a measure of the energy content of disturbances. It is the all-important quantity when rms detectors, such as ears, are involved. As channel bandwidth is used more effectively however, the requirements on disturbances become more stringent. For synchronous modems, making several thousand multi-state analog threshold decisions per second, disturbance sensitivity is more closely measured by instantaneous (peak) noise rather than by rms noise. Further, the sensitivity of synchronous modem error rates to modulation impairments is determined by the modem encoding scheme; e.g., phase-encoded modems are only marginally susceptible to amplitude disturbances.

The typical notched noise measurement is C-message weighted, a weighting which discriminates heavily against power line frequencies. The signal is weighted by a specific bandpass filter. The test tone is removed with a narrow band-reject (notch) filter. The remainder is detected with an rms or quasi-rms detector, the output of the detector is averaged with a specified fractional-second-averaging time constant, and the result is displayed as a number. Since the number is in dBm or dBrn, a logarithmic element is included. The following information is removed by the above set of rules:

1. Crest Factor. This is the ratio of peak to rms noise. It is highly waveshape dependent. For white noise on a VF channel this factor is 8 or 9 to 1, for a sine wave it is 2.8 to 1. The 'spikiness' of the noise is completely masked in an rms measurement.

2. Phase Relationship of Impairments to Tone. Phase modulation or amplitude modulation may, depending upon the nature of the modem encoding scheme, be less harmful than random noise.

3. Harmonic Relationship of Impairments to Tone. Certain harmonics are more significant in data impairment than their contribution to rms noise.

4. Phenomena near the tone frequency, such as low frequency modulation impairments, will be attenuated or eliminated because of the bandwidth permitted in the notching (band reject) filter.

However, if the noise is 'typical' in character, i.e., the large majority of cases, the measurement result is valid for establishing facility/modem compatibility. If the noise is unusually 'spikey', if low frequency modulation is present, if an SFI tone near the modem clock frequency is present, or if the impairment is entirely in the 'wrong' direction (e.g., phase modulation on a facility which is to be used with a phase-cndoded modem), the line may not move data. On the other hand if the impairment is primarily SFI remote from the modem clock frequency, or is primarily in the 'right' direction (e.g., amplitude modulation on a facility which is to be used with a phase-encoded modem), the measurement result may be unduly conservative.

c. NEW INFORMATION

The suppressed-tone phasor-display technique provides two new kinds of information. One of these is information about defined phenomena which is rejected by conventional instrumentation because of the mechanization rules. This includes phenomena such as:

1. Phase Jitter. Because it was 'discovered' as a problem after the advent of vestigal-sideband and phase-encIded modems, phase jitter is not a voice-technology-based measurement; as a result, it is defined on a peak to peak basis. However, prior to the existence of suppressed-tone phasor-domain measurement it was not possible to resolve phase modulation and the effects of noise on phase. These quantities were therefore lumped and called phase jitter. In order to minimize the effects of noise on the reading, the bandwidth of impairments examined was restricted to the region between 20 and 300 Hz around the test tone.

As might be expected, due to the natural perversity of things, significant incidental phase modulation exists outside this range. Recently the problem of incidental PM below 20 Hz has surfaced, potentially obsoleting existing jitter sets. Jitter set manufacturers, including ourselves, are offering modification kits, i.e., patched-up units which will suffice until the next exception is "discovered". It is already clear, from real time examination of low frequency jitter with the PB-1, that none of the instrumentation goes low enough in frequency. This appears to be the result of a mechanization problem, the existing phase lock loops limit the low frequency response. This difficulty has been circumvented with the PB-1 by measuring not only the magnitude but the frequency of the jitter, i.e., counting the number of cycles in 5 or 10 seconds. This permits application of a correction factor when the jitter is below 3 Hz, where the meter displays roll of significantly, i.e., a significant fraction of low frequency jitter cases.

A more subtle impairment is that of incidental modulation at frequencies higher than the test tone. The lack of sideband symmetry, due to foldback of the lower sidebands, makes this condition virtually impossible to recognize with instrumentation other than phasor domain instruments. With the PB-1 in the unfiltered mode there is no confusion except for a narrow band of modulation frequency around the tone frequency and a second narrow band around the second harmonic of the tone frequency. High frequency modulation is considered to be a relatively rare problem or is not considered at all. In this respect it resembles other impairments which did not "exist" when they could not be identified.

2. Notched Noise. See discussion above.

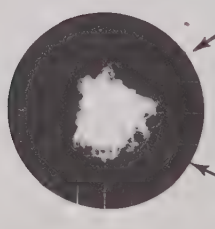
3. Transient Phenomena. This is perhaps the least defined area of all. It is necessary to define rise time, duration, interval, and phase coherence (phase hits and gain hits are phase coherent: impulse hits are not) in order to 'count' a hit. These quantities vary continuously in the real world. Hits which are below threshold or are too slow in transition, too brief, or occur too soon after previous hits are ignored. For any of these reasons, either of two hits which differ only slightly may be counted while the other hit may be ignored.

4. Amplitude Jitter. Not now routinely measured.

The second new kind of information, which is associated with the harmonic modes, is the measurement of phase intercept distortion. This is another one of those normally unmeasured quantities which characterizes a significant fraction of the 'mystery' problems, i.e., channels which meet published requirements but which will not pass data.

14. DISCUSSION OF ACCURACY

It has been suggested that the suppressed-tone phasor domain technique is less accurate than conventional measurement techniques. One perspective on this matter is suggested by the following discussion of notched noise in which five "pure" impairments, identical in rms value, are characterized in peak-to-peak and in phasor domain terms. Consider a holding tone of 1004 Hz, 0 dBm (600 ohms) in the presence of below-tabulated steady-state impairments. The notched noise is as indicated:

IMPAIRMENT	PEAK TO PEAK MILLIVOLTS	RMS VALUE	PHASOR DOMAIN REPRESENTATION
Single Frequency Interference	69	-25.0 dB	
2nd Harmonic	69	-25.0 dB	
Amplitude Modulation	98	-25.0 dB	
Phase Modulation	98	-25.0 dB	
White Noise	220	-25.0 dB	

Noise photograph - shorter exposure, to delineate peaks. Although peaks are faint in photograph, they are clearly visible in the live display.

All Photos Taken At Same Sensitivity

The above impairments are different in character. They are the result of malfunctions in different parts of the facility, and they are entirely different in their effects on high speed data. The only thing they have in common is their C-message weighted notched noise readings which agree with each other to within 0.1 dB, i.e., the conventional technique describes these highly diverse phenomena identically.

Which is the more "accurate" measurement of the impairments, the phasor domain presentation or the rms reading? Clearly, measurement "accuracy" must be considered in the light of measurement purpose. If a facility is being checked for its behavior while through-putting information for rms detectors, such as ears, or for meeting an rms-defined index requirement, the conventional technique provides more accurate information. If the purpose of measurement is to find out what is going on for facility diagnostics, or to classify a facility's performance relative to instantaneous value detectors such as modems, then phasor domain measurements are more "accurate".

The confusing factor is noise. In the presence of noise the phasor domain display provides results which are harder to "read". This happens because the impairment itself is less well defined, and the reflection of this fact in the display is not a weakness but a strength. The conventional technique reduces this same poorly delineated information to a well delineated number via filtering, detection, and time averaging. The experienced craftsman will try to read through the time-averaged technique by taking into consideration the "liveliness" or "jumpiness" of the meter reading. In fact the only significant objection to digital readouts remains their lack of suitability for estimating the center value and spread of "noisy" readings.

A discussion similar to the above can be developed for transient phenomena (hits). Here the problem is even more complicated because the mechanization for counting requires not only magnitude but phase correlation, duration, dead time, and rate of change definitions to establish what will be counted and what will not. Such definitions provide a large continuum for operation of Murphy's Law phenomena.

The suppressed-tone phasor domain technique can be used to generate highly reproducible results. Consider, illustratively, the following possibilities:

1. The use of memory display to "paint" a time record of the peak impairments over a specified period (accompanied by a photograph or a recording for a permanent record).

2. Use of an event triggered memory display with analog delay to capture an accurate record of transients (also accompanied by a photograph or a recording for a permanent record).

3. Graticule overlays which block the display in the facility's "go" region so that any visible trace is an alarm condition.

However the next step in extension of the technique involves facility performance definitions, thus its direction must await definition by an entity with industry-wide stature such as AT&T or CCITT.

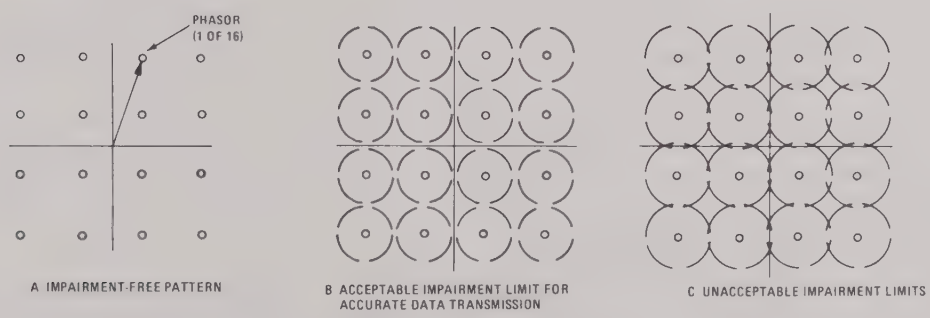


Figure 34 Decision Space Diagrams

15. NON-STANDARD APPLICATIONS

In addition to its fast and informative facility diagnostic capability the technique lends itself to a variety of applications which are less obvious. Some of these are described below.

a. GO/NO-GO EVALUATION OF LINE-MODEM COMPATIBILITY

High-speed digital data is transmitted over voice-frequency channels by synchronous modems employing phase and/or amplitude modulation of audio-frequency carriers or 'clocks'. The receiving modem 'recovers' the clock frequency from the transmitted signal; i.e., synchronizes to that clock frequency. Relatively small line impairments can cause errors in such modems; large line impairments can cause momentary loss of synchronization.

A synchronous modem transmits N bits of binary data per cycle of a clock frequency by sending one of 2^N encoded states of phase and/or amplitude modulation of that clock frequency, and changing the state once each clock cycle. For example, 16 possible states of the clock frequency may be represented by 16 phasors, as shown in Figure 34A. This type of coding is called QAM, denoting an encoding scheme combining both Quadrature and Amplitude Modulation. The entire area of Figure 34A represents the modem 'decision points', the 'constellation' or 'eye' pattern of 'decision points' represents the locations of the tips of the 16 phasors.

Line disturbances occuring at any instant during transmission of any phase-and-amplitude-modulated signal will add instantaneously and vectorially to that signal, shifting the tip of the phasor being transmitted at that instant, so the receiving modem will not see the 16 stationary points of the constellation pattern, but will see smeared areas around the theoretical points. The receiving modem can operate without error only if adjacent smeared areas do not overlap. As shown in Figure 34B, it is possible to define a geometric figure bounding the maximum permissible area within which errors will not occur. Disturbances causing overlapping smears, as in Figure 34C, will cause errors. Note that the permissible area must frequently include an allowance for harmonic distortion which is measured separately, and an allowance made for the phasor tip smear resulting from static line impairments such as gain and envelope delay distortion.

When a test tone is transmitted over a voice-frequency channel, line disturbances will add vectorially to the tip of the received tone phasor and smear that tip over an area, in exactly the same way as they would smear the tips of the 16 QAM phasors over 16 areas in the modem decision space. If the received tone is examined by a Suppressed-Tone Phasor Domain Line Analyzer, the steady-state tone is suppressed so that (in the VECTOR NOTCH mode) the disturbances can be displayed on an expanded basis. This is equivalent to continuous high-resolution examination of a single modem decision point. It can immediately be determined whether the line disturbances remain within the permissible area (GO condition) or extended beyond the permissible area (NO-GO condition). The PB-1 views all the instantaneous components of peak noise, thereby identifying not only disturbances which have been classified and are now measured by conventional test equipment, but also disturbances that have not yet been classified, and which are now ignored, even though they affect modem performance.

Because the frequency content of a modem signal may extend beyond one octave, and because harmonic distortion modifies the decision space, the line-evaluation procedure should include measurements of 2nd and 3rd harmonics. Measurement of the in-phase and quadrature components of disturbances, and the harmonic distortion, defines line performance with respect to modem requirements.

b. EVALUATING DUAL DIAL BACKUP LINES

As a corollary of GO/NO-GO line evaluation capability, the technique can be used to simplify and expedite the procedure of establishing a two-way Dial Network backup for private or leased lines between a near terminal and a marginally-attended or unattended far terminal, by reducing the problem from that of simultaneously finding two acceptable lines at each dialing to that of finding one acceptable line at each dialing.

When either or both of a pair of private or leased lines fails to transmit data satisfactorily between a near or local terminal and a far or remote terminal, it is common to use the Dial Network as a backup, by dialing two lines between the terminals for full duplex operation. To be certain that the two backup lines are usable in the intended directions of use, they must be checked out in those directions. Assuming that the means of verifying good lines is at the near terminal, the lines are looped back at the far terminal and digital data (in the case of digital loopback) or a test tone (in the case of analog loopback) are sent around the loop from and to the near terminal. If the loop-around signal is not satisfactory, two new lines are dialed and the test is repeated, until a satisfactory loop is obtained. Note that two lines must be rejected if the loop is not acceptable, even though one of the lines may be good. This necessitates dialing and testing until two simultaneously acceptable lines are found.

The go/no-go phasor approach requires that only one satisfactory line be found at a time, as follows. The far-end transmit line is dialed and a tone is sent along this line to a PB-1 at the near end (Figure 35A). If the line is not satisfactory, alternate lines are dialed and tested until a "go" line is found. That line is held, and the far-end receive line is dialed. This line is looped to the far-end transmit line, and the near end sends a tone through the loopback to the test instrument (Figure 35B). Alternately at this point a digital signal may be sent around and the modem itself used as the test device. Since the far-end transmit line is known to be good, only far-end receive lines need be dialed, until the loopback connection is good.

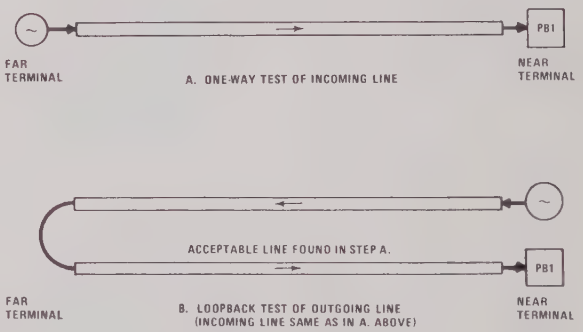


Figure 35 Evaluating Dual Dial Backup Lines

c. TRACKING NOTCH-FILTER FOR OTHER INSTRUMENTS

Since the instrumentation suppresses the steady-state component of received tone, leaving only the disturbances on that tone as 'notched noise' to be analyzed and displayed, it acts as an extremely narrowband notch filter. For example, the existing instrument can track any one of five input tones (404, 804, 1004, 1704, and 2804 Hz) over a ±8% frequency range. This notched noise is available as an electrical output for use by other instruments, as shown in Figure 36. This notched noise differs from the output of a conventional notch filter in that it is relative to a "normalized" test tone, and that phase relationships between the notched noise and the tone are not distorted. When fed to conventional noise meters, the notched noise output causes those meters to operate as notched noise meters. The same output permits impulse counters to operate on lines in the presence of holding tones without being triggered by those tones. The notched noise can also be fed to the vertical input of a cathode-ray oscilloscope for display of notched noise in the time domain. This permits estimation of the frequency of any predominant component of the notched noise. A useful display results if the external oscilloscope is used in an X-Y mode. The horizontal axis

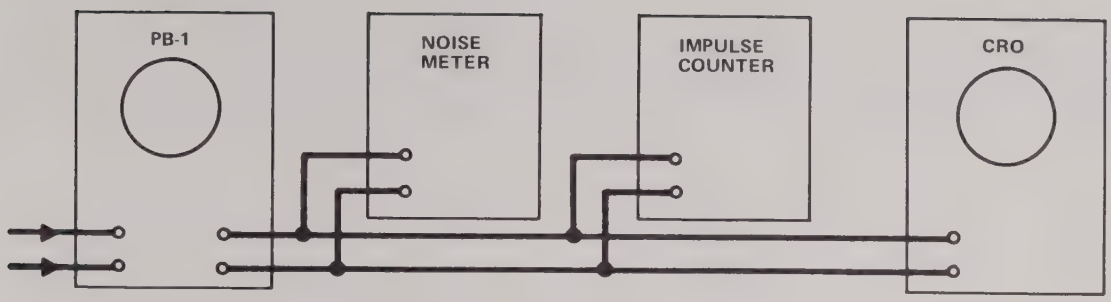


Figure 36 PB-1 VF Line Analyzer as a Tracking Notch Filter

is driven by the input signal (or by the PB-1 local oscillator as available at the rear connection) and the vertical axis is driven by the notched noise.

In the case of a normally noisy line, the noise components near the tone frequency cause continuous small errors in the tracking loops which results in a tone frequency component which is normally well below the background noise level inducing it. In the case of low frequency modulation impairments this effect is more pronounced.

d. CHECKING QUALITY OF TEST-TONE SOURCES

It is desirable to check station test-tone sources periodically. This is done by patching the instrument directly to the tone source and observing the source output with maximum sensitivity in the fundamental and harmonic modes. This assures that when a test-tone source is used for testing transmission channels, there are no disturbances (i.e., harmonics, level and/or frequenty shifts, phase and/or amplitude modulation, hum, noise, etc.) on the test tone what would be erroneously attributed to the transmission channels under test.

e. IDENTIFICATION OF FACILITIES BY SIGNATURES

The time constants of the AGC loop and of the Phase-Lock Loop are such that both loops operate rapidly enough to recover from transients within the 1/7 second dead-time interval of hit counters, but do not operate so rapidly that they mask hits, steps, or other transients. The hardware therefore responds to transients in ways that identify them acoustically. Gain or phase hits 'pull' the tracking loops, thus momentarily degrading the notch, causing a 'ping' as the tone 'leaks' through the recovery period. Low-frequency steady-state modulation also pulls the loops, causing a 'wow'. Impulse hits do not pull either tracking loop; they cause a 'pop'.

The visual and acoustic outputs frequently permit identification of telephone transmission facilities through which the test tone may pass. FDM, PCM, and Copper facilities have characteristic impairment; patterns which frequently permit identification.

Although there is no substitute for extended experience to develop facility identification capability, the following represent a starting point.

FDM (Figure 18)

Patterns in which phase jitter predominates usually indicate that FDM is involved. Low-frequency jitter is characteristic of older FDM's. Continuous small phase hits, visible and audible, order a magnitude a few degrees, are an indication the facility is passing through the heavy traffic area. Circular motion or high angular mobility of the harmonic distortion spot frequently indicates sync supply problems.

PCM (Figure 22)

Vertical excursion (amplitude jitter) exceeds horizontal, and harmonic distortion frequently is much larger than in FDM channels, particularly in older channel banks. VECTOR NOTCH pattern is sensitive to test tone frequency. Tone sources at 1000 Hz may result in aliasing products near 2 KHz and 3 KHz which moves the harmonic spot dramatically. Characteristic grinding sound. Excessive distortion and large radial steps in distortion spot may indicate timing or compandor problems.

Copper

No modulation impairments of any kind. Harmonic distortion may be present.

BRADLEY TELCOM CORP. • 117 Fort Lee Road • Leonia, New Jersey 07605 • Telephone (201) 461-5903

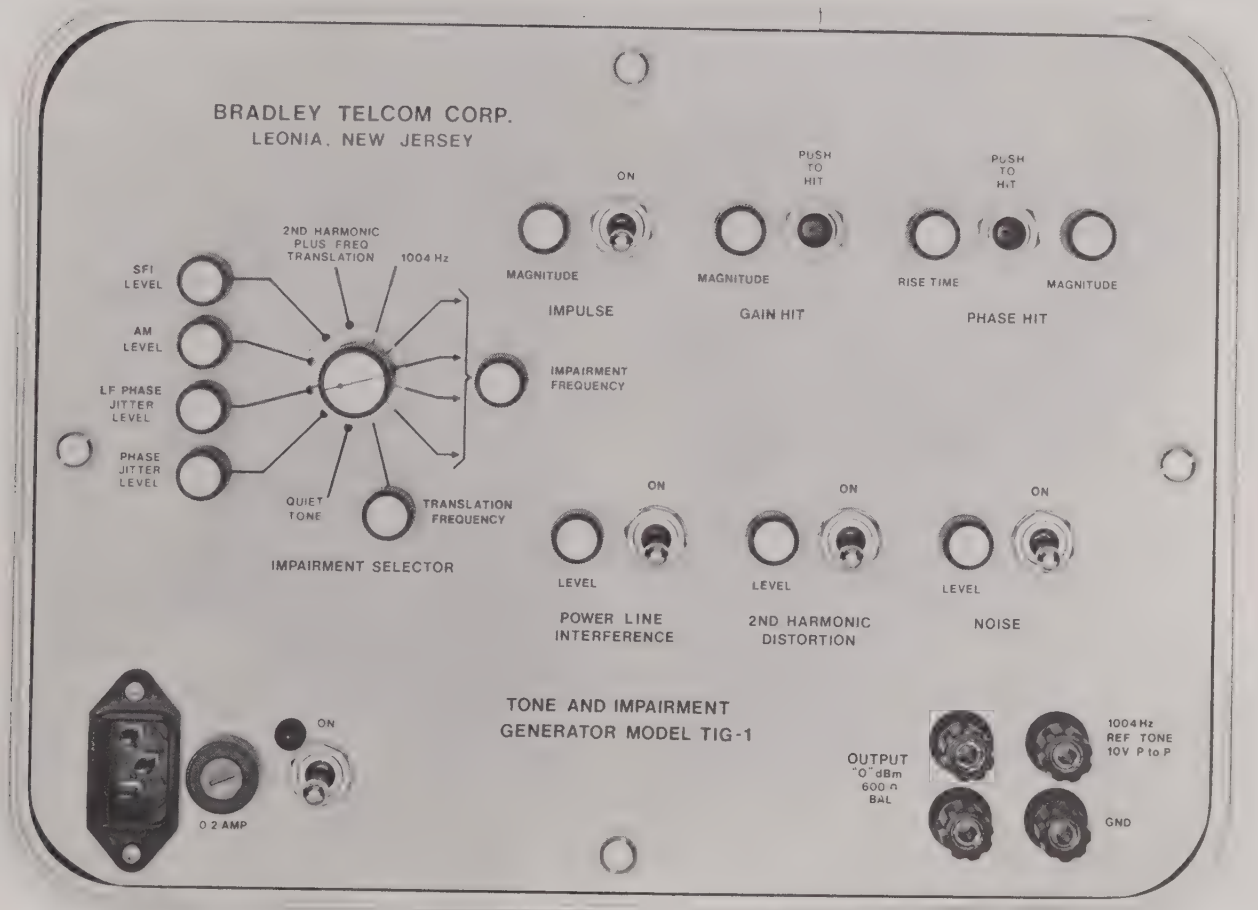
MODEL TIG-1 AND TIG-1E TONE AND IMPAIRMENT GENERATOR

FOR INSTRUCTED TRAINING
FOR CRAFTSMAN SELF-TRAINING

Demonstrate impairments
Demonstrate use of test equipment
Set up test problems

FOR ANALYSIS OF UNUSUAL IMPAIRMENT COMBINATIONS

Set up TIG-1 experimentally to match observed line characteristics



This "Trainer Box" unit realistically simulates a wide variety of line impairments. These are generated by methods similar to those employed in our 2A/2B Line Simulator. Significant economy is achieved by limiting operation to manipulation of an internally generated test tone only, and by providing impairments that are variable but not calibrated. The impairment ranges are chosen to be representative and the impairments may be mixed to achieve excellent simulation of FDM, PCM, and copper facilities. The unit is sufficiently low in cost that it may be justified as central office equipment for ongoing self or instructed training of craft.

BRADLEY TELCOM CORP.

117 Fort Lee Road
Leonia, New Jersey 07605
Telephone (201) 461-5903

MODEL TIG-1 AND TIG-1E TONE AND IMPAIRMENT GENERATOR

FUNCTIONAL DESCRIPTION

The TIG-1 generates one of six selectable outputs as follows:

A. Pure 1004 Hz tone: 0 dBm at 600 ohms, dc blocked for 200 volts. All impairments more than 46 dB down.

B. Phase Modulation: 1004 Hz, 0 dBm tone with phase modulation adjustable from 5 to 15 degrees, 30 to 300 Hz.

C. Low-Frequency Phase Modulation: 1004 Hz, 0 dBm tone with phase modulation adjustable from 10 to 30 degrees, 0.5 to 5 Hz.

D. Amplitude Modulation: 1004 Hz, 0 dBm tone with amplitude modulation adjustable from 5 to 15%, 30 to 300 Hz.

E. Single-Frequency Interference: 1004 Hz, 0 dBm tone with SFI tone adjustable from -14 to -26 dB SFI tone at 240 to 2400 Hz.

F. Second Harmonic Distortion Followed by Frequency Translation: 1004 Hz, 0 dBm tone with nominally -30 dB 2nd harmonic distortion; translation frequency adjustable over at least ± 6 Hz.

The following impairments may be added to the output selected above, singly or in combination:

1. Gaussian Noise: Adjustable from -25 to -35 dBm.
2. Second Harmonic Distortion: adjustable from -25 to -40 dB.
3. Power Line Interference: adjustable from -14 to -26 dB.
4. Phase Hits: manually initiated and terminated, adjustable 5 to 25 degrees amplitude and 3 to 100 milliseconds transition time.
5. Gain Hits: manually initiated and terminated, adjustable 1 to 3 dB amplitude.
6. Impulse Hits: 2 per second, adjustable -5 to -15 dB.

PHYSICAL DESCRIPTION

The unit is packaged in a 9 x 12 x 4½" attache case with hinged cover, and with integral handle and latches. There is room within the case for line cord, test cords, and instruction book. The unit weighs 7 pounds.

POWER REQUIREMENT

TIG-1 90 to 125 volts, 50 to 60 Hz, 50 ma
TIG-1E 190 to 250 volts, 50 to 60 Hz, 25 ma

BRADLEY TELCOM CORP. ● 117 Fort Lee Road ● Leonia, New Jersey 07605 ● Telephone (201) 461-5903

TRANSPARENT LINE GENERATOR MODELS NNE 1000 AND NNE 1000R

WITH A SINGLE INEXPENSIVE TRANSPONDER

Extend Test Center Dynamic impairment measurement capability and diagnostic expertise to:

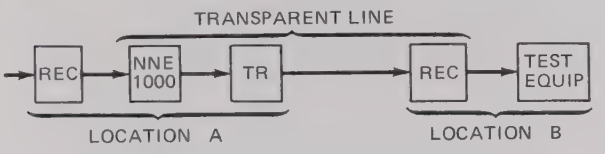
- Subscriber locations
- Less well-equipped C.O.'s
- Intermediate point VF appearances
- Back-to-back channel bank locations
- Unattended locations

Sectionalize Troubles at:

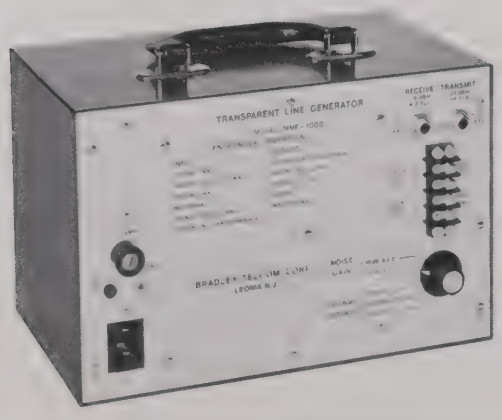
- Unattended microwave stations
- Multiple carrier interface
- Intermediate point VF appearances

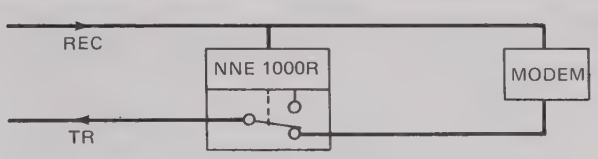
WHAT IT IS

Complete testing of a facility normally requires signal generating instruments, signal analyzing instruments, and maintenance personnel capable of interpreting results, at every terminal. The NNE unit permits the creation of a test loop in which one or more legs of the loop are made "transparent" thus requiring analyzing instruments and skilled personnel at only one location in a test loop. A facility which terminates at Location A may be tested from Location B with the connection between A and B becoming, in effect, a long test cord. The NNE is available in three versions designated NNE 1000, NNE 1000R, and NNE 1000 TTR.

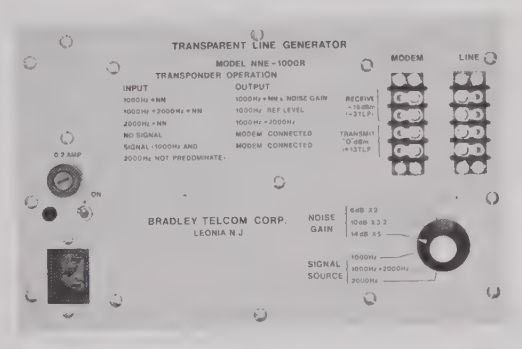


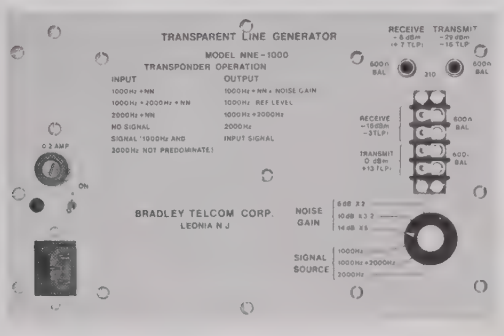
The NNE 1000 is a manually patched unit which accommodates either central office test levels (-6 dBm receive, -29 dB transmit) or subscriber site levels (-16 dBm receive, 0 dBm transmit), depending upon patching. Thereafter the operating modes of the unit are controlled via the signal path. Five modes are provided, as described below, to permit fully diagnostic operation for Loopback, Remote Point, and Third Point testing.



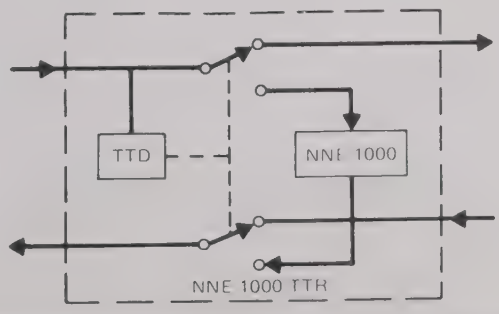


The NNE 1000R accommodates subscriber location levels (-16/0). It is automatically switched either by its own signal path to place a 4-wire line in a test mode, or via DDD to test a 2-wire line. In either case the NNE 1000R output is substituted for the normally connected equipment, see above, during that period when its input continuously receives signals in which 1000 Hz or 2000 Hz predominate.





The NNE 1000 TTR comprises a modified NNE 1000 with built-in specialized touch tone decoder (TTD). The TTD is controlled by a standard touch tone pair. The unit includes a four-pole double-throw transfer relay which latches in either position.



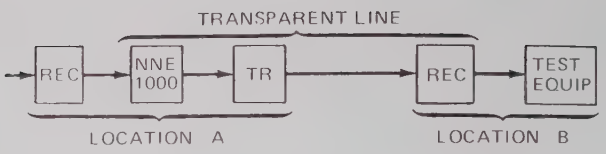
WHAT IT DOES

Line faults can be divided into two categories, those dynamic impairments which generate spurious noise, sidebands, or harmonics, in the presence of a test tone, and those impairments which characterize the steady state facility performance, i.e., gain vs frequency, envelope delay vs frequency, and return loss. The spurious signals generated by the dymanic impairments are all included in the quantity notched noise. It is these impairments for which the facility A to B above is rendered transparent by the NNE units. This includes:

Noise (Background, Quantizing, etc.)
Impulse Hits
Phase Jitter
Phase Hits
Amplitude Jitter
Gain Hits
Harmonic Distortion
Gain/Loss
Phase Intercept Distortion (Time Variation)
Frequency Translation
Single Frequency Interference

Impairments not included are the facility's basic linear properties, i.e., gain vs frequency, envelope delay vs frequency, and return loss. The NNE 1000 is itself transparent except for tones near 1000 Hz and 2000 Hz so that conventional looparound tests are possible (Mode 5 below).

Notched noise includes all disturbance components except for the tone, i.e., background noise, modulation products, harmonic products, and transient disturbances of all kinds. The NNE selectively amplifies the notched noise relative to the test tone by a known enhancement factor *without changing the phase relationship* between the tone and the notched noise components, Mode 1 below. The notched noise enhancement factor, called "NOISE GAIN" is switch-selectable at 6 dB, 10 dB, or 14 dB. The signal launched at A is then so noisy as to make negligible the contribution of the notched noise introduction in the "transparent" facility. The measurements made at B are divided by the enhancement factor to establish their values at A.



In order to ensure that the transmission facility from A to B is not so poor as to invalidate the above assumption, Mode 2 below is provided. Mode 2 results in the NNE launching a pure tone at reference level into the return channel so that it can be checked for gain and dynamic impairments.

There is an overall gain or loss provided in the NNE units depending which input/output connections are used. In the NNE 1000 one set of connections (310 jacks) accepts -6 dBm nominal input and provides a -23 dB loss to the output for use at +7/-16 TLP's (central office). The other set (a 4-point barrier strip) accepts -16 dBm nominal input and provides 16 dB gain for use at -3/+13 TLP's (subscriber location).

The NNE 1000R provides two 4-point barrier strips, one for the line connection and the other for equipment connection. The receive level is nominally -16 dBm and the output level is +16 relative to the received signal.

OPERATING MODES

The operating modes are tabulated below:

MODE	INPUT	OUTPUT	OUTPUT LEVEL or INPUT-TO-OUTPUT GAIN -3/+13 TLP (Barrier Strips)	OUTPUT LEVEL or INPUT-TO-OUTPUT GAIN +7/-16 TLP (310's)
1	1000 Hz + Notched Noise	Input + (Notched Noise) x (Noise Gain Factor). Relay transfers for NNE 1000R	(Rec Level +16 dB)	(Rec Level -23 dB)
2*	1000 Hz + 2000 Hz + Notched Noise	1004 Hz pure tone. Relay transfers for NNE 1000R	0 dBM	-29 dBm
3	2000 Hz + Notched Noise	1004 Hz pure tone + 2008 Hz Harmonic. Relay transfers for NNE 1000R	0 dBM	-29 dBm
4	No Signal (Signal Level 12 dB below nominal)	2008 Hz Tone, NNE 1000**	0 dBm	-29 dBm
		Received Signal, NNE 1000R	(Rec Level +16 dB)	(Rec Level -23 dB)
5	Any Signal within 12 dB of Nominal in which neither 1000 Hz or 2000 Hz predominate	Received Signal	(Rec Level +16 dB)	(Rec Level -23 dB)

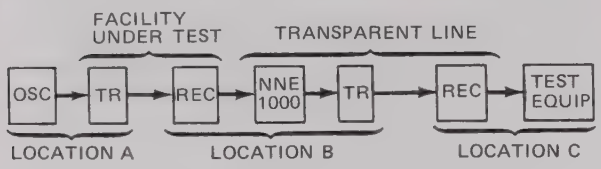
In addition to its "NOISE GAIN" position, the "MODE" switch has three "SIGNAL SOURCE" positions designated 1000 Hz, 1000+ 2000 Hz, and 2000 Hz. These are the control inputs for the first three transponder modes above. This permits an NNE unit to be used as a signal source to control remote NNE units; i.e., to be used as the oscillator in the block diagrams on the following pages.

* This command signal can be generated by another NNE or by the Bradley PB-O Oscillator, using the ADD HARMONIC switch of the oscillator.

** If a modem is playing through the NNE 1000, the appearance of a 2000 Hz indicates that the channel gain has dropped 12 dB below nominal.

REMOTE POINT TEST

Two-wire facility from A to B to be tested on location C.



CHECK TRANSPARENT LINE

1. Launch (1000 Hz + 2000 Hz) from oscillator. This establishes MODE 2 at NNE 1000, i.e., it transmits a pure 1004 Hz tone at reference level.
2. Transparent line is tested to make certain that it is a relatively normal line, and its 1000 Hz gain is measured.

CHECK FACILITY UNDER TEST

3. Launch 1000 Hz Tone from oscillator. This establishes MODE 1 at NNE 1000.
4. NNE 1000 returns tone at remote received level (adjusted for TLP) plus enhanced notch noise.
5. Remote receive level may be inferred from 1000 Hz gain calibration (2. above). Remote site received notch noise is determined by dividing local site readings by the "NOISE GAIN" setting.

STRAIGHT THROUGH CONNECTION

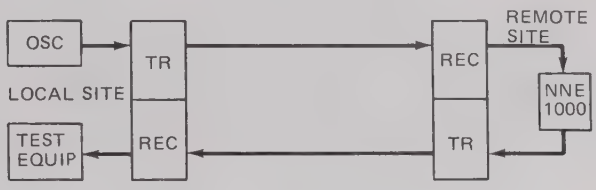
6. Transmit tone not within 5% of 1000 Hz or 2000 Hz, or complex signal in which 1000 Hz or 2000 Hz tones do not predominate. This establishes MODE 5 at NNE 1000 which then becomes transparent. The complex signal may include frequency "combs" of 10 or more equal amplitude tones which include 1000 Hz and 2000 Hz as elements of the comb.

SET-UP DIAGNOSTICS

7. Open circuit A to B — NNE 1000 detects "no signal" and assumes Mode 4. The 2000 Hz tone thus transmitted to C identifies the open circuit location.
8. Open circuit B to C — NNE 1000 generates an output in any of its modes. Thus if no signal is received at C, this indicates an open circuit in the link from B to C.

LOOPBACK TEST

Four-wire facility to be tested in each direction from a location at one end.



CHECK "REMOTE TO LOCAL" DIRECTION

1. Launch (1000 Hz + 2000 Hz) from oscillator. This establishes Mode 2 in the NNE 1000.
2. NNE 1000, in Mode 2, launches pure 1004 Hz tone at reference level toward local site.
3. Local receive line is tested and its 1000 Hz gain calibrated.

CHECK "LOCAL TO REMOTE" DIRECTION

4. Launch 1000 Hz from oscillator.
5. Remote site NNE 1000, in Mode 1, returns tone at remote received level (adjusted for TLP) plus enhanced notch noise.
6. Remote receive level may be inferred from 1000 Hz gain calibration (3. above). Remote site received parameters are determined by dividing local site readings by the "NOISE GAIN".

CONVENTIONAL LOOPBACK TEST

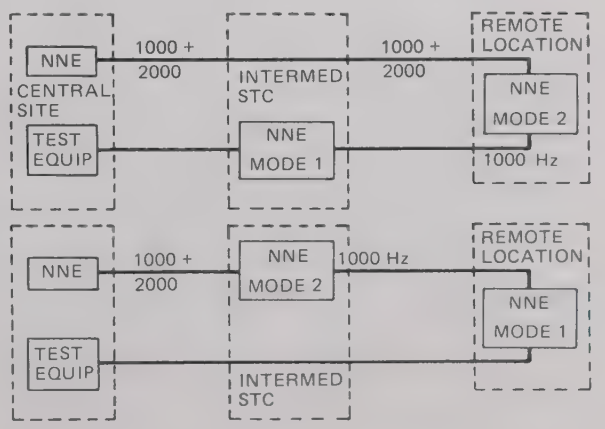
7. Transmit tone not within 5% of 1000 Hz or 2000 Hz, or complex signal in which 1000 Hz or 2000 Hz tones do not predominate. This establishes MODE 5 at NNE 1000 which then becomes transparent. The complex signal may include frequency "combs" of 10 or more tones which include 1000 Hz and 2000 Hz as elements of the comb.

SET-UP DIAGNOSTICS

8. Open circuit, local to remote — NNE 1000 detects "no signal" and assumes Mode 4. The 2000 Hz tone thus returned identifies the open circuit location.
9. Open circuit, remote to local — NNE 1000 generates an output in any of its modes. Thus if no signal is received at the local site, this indicates an open circuit in the return path.

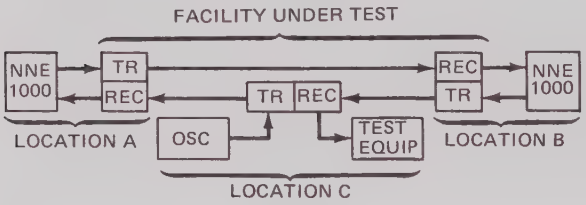
TESTING VIA AN INTERMEDIATE STC

Refer to figure, testing via an intermediate STC can be accomplished using a single NNE 1000 at the STC and either an NNE 1000 or an NNE 1000R at the remote terminal. The NNE transpondor at the STC is manually shifted between the transmit and receive side.



THIRD POINT TEST

Two-wire facility from A to B to be tested from location C. Tests to be fully controlled from C.



CHECK FACILITY "B TO C"

1. Launch 2000 Hz C toward A. This places NNE 1000 at A in Mode 3.
2. Location A transmits 1000 + 2000 Hz tone. This places NNE 1000 at B in Mode 2.
3. Location B transmits pure 1004 Hz tone at reference level toward C.
4. Test equipment at C is used to make certain that line is relatively normal, and its 1000 Hz gain is measured.

CHECK FACILITY "A TO B"

5. Launch 1000 Hz + 2000 Hz C toward A. This establishes NNE 1000 at B in MODE 2.
6. Location A transmits pure 1004 Hz tone at reference level toward B.
7. NNE 1000 at B, in Mode 1, sends tone at received level (adjusted for TLP) plus enhanced notch noise toward C.
8. Received level at B may be inferred from 1000 Hz gain calibration (4. above). Location B received parameters are determined by dividing location C readings by "NOISE GAIN" setting.

CONVENTIONAL LOOPAROUND TEST

9. Transmit tone not within 5% of 1000 Hz or 2000 Hz, or complex signal in which 1000 Hz or 2000 Hz tones do not predominate. This establishes MODE 5 at NNE 1000 which then becomes transparent. The complex signal may include frequency "combs" of 10 or more tones which include 1000 Hz and 2000 Hz as elements of the comb.

SET-UP DIAGNOSTICS

10. Open circuit C to A — NNE 1000 at A is placed in MODE 4. NNE 1000 at B is thereby placed in MODE 2. Location C receives 1000 Hz + 2000 Hz indicating open circuit C to A.
11. Open circuit A to B — NNE 1000 at B is placed in MODE 4. Location C receives 2000 Hz indicating open circuit A to B.
12. Open circuit B to C — Absence of signal at C indicates open circuit B to C.

SPECIFICATIONS NNE 1000

As transponder

Input - 600Ω, Balanced, dc blocked for 200 volts, either - 16 + 6/-12 dBm or -6 + 6/-12 dBm

Output - 600Ω, Balanced, dc blocked for 200 volts +16 or -23 dB relative to input for Mode 1 and Mode 5, 0 dBm or -29 dBm for Modes 2, 3, and 4

"NOISE GAIN" - Applicable to Mode 1, NNE 1000 mode switch selectable at +6 dB, +10 dB or +14 dB "NOISE GAIN"

CONTROL

Mode 1 initiated by - 1010 Hz ± 20 Hz not more than 2 dB below average received level.

Mode 2 initiated by - 1010 Hz ± 20 Hz not more than 2 dB below average received level plus 2020 Hz ± 40 Hz. The transition to Mode 2 occurs when the level of second harmonic exceeds -20 dB relative to the 1000 Hz fundamental.

Mode 3 initiated by -20 Hz ± 40 Hz not more than 2 dB below average received level.

Mode 4 initiated by - received level more than 12 dB below nominal received level.

Mode 5 initiated by - received level within 12 dB of nominal and no 1010 ± 20 Hz or 20 ± 40 Hz component greater than -10 dB relative to received level.

Switching activation requires at least 2 seconds of command tone to cause a transition. Removal of the command tone will cause reversion to Mode 4 or 5 two seconds after that tone is removed.

As Signal Source

Output - 600Ω, Balanced, dc blocked for 200 volts, 0 dBm

"SIGNAL SOURCE" positions of NNE 1000 "mode" switch selects output tone or tones of 1000 Hz, 1000 Hz + 2000 Hz, or 2000 Hz.

1000 Hz tone - all impairments (phase jitter, amplitude jitter, harmonic distortion, hum) - individually - 60 dB relative to tone.

1000 Hz tone - as above plus 2000 Hz 2nd Harmonic 16 dB below tone.

2000 Hz tone - at 0 dBm or -29 dBm.

SPECIFICATIONS NNE 1000R

As above, except that subscriber location levels only are accommodated, i.e., -16 dBm nominal receive and 0 dBm nominal transmit level, and the input impedance is bridging. Two 4-point barrier strips are provided, one for the line side connection and one for the drop (modem) side. The NNE 1000R is bridged across the line when the receive signal is of the form required to induce Modes 1 through 3 above, a two-pole transfer relay is activated. This is internally wired to remove the connection between the drop side transmit and the line, replacing this connection with the transmit side of the NNE 1000R. The NNE is then in one of its three modes.

APPLICATIONS

NNE 1000

SUBSCRIBER LOCATION LOOPBACK (SEE LOOPBACK TEST ABOVE)

Conventional testing of a loopback-connected four-wire line results in measurement of the instantaneous sum of the impairment contribution in each path. Some impairments may cancel, others may add linearly, others may add on a power (rms) basis. It is thus desirable to test each path separately: conventional loopback testing is only an expedient. To test each path one way using the NNE, the modem is unplugged from the four-wire line and replaced by the NNE 1000. The full technical expertise and test equipment complement of a central location can then be applied to each path. The field operation consists of replacing one plug with another. This is sufficiently simple so that the unit could be left in site and patched in when an intermittent problem occurs. The NNE 1000R permits this patching to be accomplished automatically.

CENTRALIZED MONITORING USING EXISTING DEDICATED FACILITY (SEE REMOTE POINT TEST ABOVE)

It is desirable to centralize facility testing so that high performance instrumentation and high level expertise can be multiplied in effectiveness. This has lead to systems which involve compensated dedicated test lines to reach a multiplicity of remote test nodes. Several of these systems exist in which a frequency comb is used. Such systems essentially calibrate out the steady state characteristics of test lines, and these lines are permanently assigned to the test function. The NNE 1000 is transparent to frequency combs and hence can be placed permanently in tandem with the transponder. It renders the test line effectively transparent to all those impairments which are not compensated for by the comb technique, i.e., all the components of notched noise. It is thus possible to achieve a large performance increment in an already installed access arrangement by adding a relatively inexpensive NNE 1000 at each remote site, plus one for control at the central site. Remote trouble lines can be routed to a single central location for rapid diagnostics with the PB-1 or for a slower and less complete analysis by conventional test equipment.

Only one set of such central test equipment is required to service the whole system.

CENTRALIZED TESTING, DDD OR PATCHED ACCESS

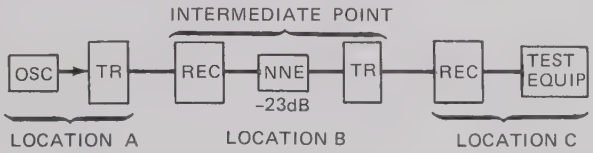
The nature of the NNE 1000 is such that it need not permanently be associated with a dedicated test line. Thus the same functions as above can be accomplished without resorting to an existing access arrangement and dedicated lines. Either the DDD network or patched lines can be used for this purpose. Again, all of the sophisticated diagnostics can be carried out by a single highly trained crew using a single high performance instrumentation set-up.

SECTIONALIZATION AT A REMOTE UNATTENDED SITE

For inaccessible locations such as may be found on multihop baseband radio systems an NNE 1000, with associated crystal oscillator, brings a pilot down to VF. VF access from a central location is provided to the NNE output so that the site can be monitored without physically going there.

INTERMEDIATE POINT VF APPEARANCE

Certain data problems are not well delineated by conventional carrier test equipment and certain VF appearances occur in what are essentially carrier equipped offices. At these intermediate point VF appearances, which are provided to permit transitions between carrier systems, the channel is routed in and out via a 23 dB pad. To permit sectionalization at such offices without trained VF personnel and without extensive VF test equipment an NNE 1000 is patched in place of the 23 dB pad. Testing and sectionalizing for dynamic impairments can then be accomplished in the facility ahead of and the facility behind the intermediate point with no further attention from intermediate point personnel and no further requirement for intermediate point VF test equipment.



1. Send 1004 Hz to check facility from A to B, i.e., NNE in Mode 1.
2. Send 1000 Hz + 2000 Hz to check facility from B to C, i.e., NNE in Mode 2.

NNE 1000R

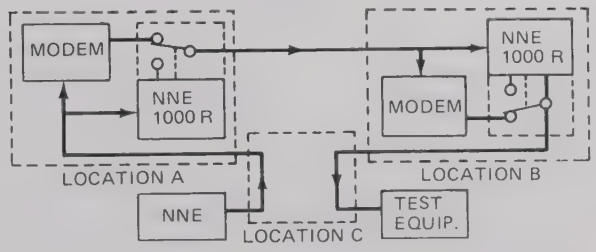
AUTOMATIC TESTING AT SUBSCRIBER LOCATION, UNATTENDED

The NNE is transparent to synchronous modem data streams. It is controlled by, and generates controlled outputs in the presence of, 1000 Hz or 2000 Hz predominant input signals.

The NNE 1000R is aimed at detection of intermittent troubles, or for use at unusually inaccessible sites. The unit is bridged on the input lines, as shown on the first page. An integral relay transfers the output line from the modem to the NNE 1000R when the appropriate command tones are present on the receive line. It is thus possible to test the path to, and the path from the remote modem, using the 4-wire line for signaling. This is accomplished without patching or any other operator intervention at the modem site.

All of the operating modes (see table) described above continue to function, permitting the full range of control.

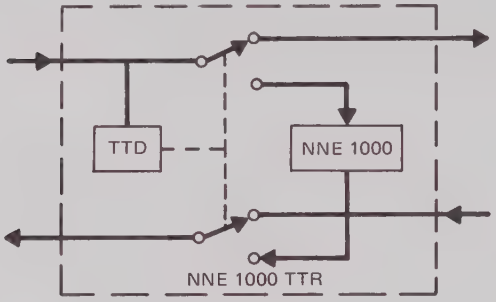
The most general case is shown below.



Alternately a DDD accessed 4 PDT relay may be used to switch the modem "out" and the NNE 1000 "in" for test purposes. A touch tone addressable version of the NNE 1000, with 4-pole latching relay, is described below. This unit is designated NNE 1000TTR: It is useful in sectionalizing impairments in multipoint and in tandem facilities.

FUNCTIONAL DESCRIPTION

The NNE 1000—TTR comprises a modified NNE 1000 with a built-in specialized touch tone decoder (TTD). The TTD is controlled by standard touch tone pairs. The unit includes a four-pole double-throw transfer relay which latches in either position.



The TTD section is bridged across the receive side VF line. It recognizes a designated touch tone code (2 out of 8) as a set up command and latches a four-pole form C reed relay in its energized position. It recognizes a second designated touch tone code as a release command and unlatches the four-pole relay, returning it to its de-energized position. The switching transition time is nominally 1/2 second in either direction. The unlatch command is pre-emptive, i.e., in the simultaneous presence of the set up command and the release command, the relay resides in, or returns to, its de-energized position.

The NNE—TTR may be used to extend NNE capability to multipoint data circuits, it may be used for remote sectionalization of faults in tandem radio facilities, or it may be used as a noise-immune remotely controllable switch for placing a remote facility in either an NNE test mode or in normal operation. The noise immunity arises from the fact that at least two tones must be present and at least one tone must not be present to cause transfer to the "test" mode.

The NNE section is an NNE 1000 modified as follows:

1. The NOISE GAIN/SIGNAL SOURCE switch is removed.
2. Input and output connections are made via four four-point barrier strips.
3. The NOISE GAIN is internally selectable at 6, 10, or 14 dB, rather than panel selectable.
4. The "SIGNAL SOURCE" capability is eliminated.
5. Nominal input and output levels and terminating impedances are to be specified by the customer.

The set up command is designated as one of 15 unique tone pair combinations at the time of manufacture. The release command is common to all TTD units and is the touch tone code for the * key.

SYSTEM OPERATION

The representative system diagram shows a three point tandem facility which might comprise, for example, the VF appearances of a dedicated four-wire test channel which is monitored for purposes of sectionalizing problems on a radio system. The TTD relays are shown in their de-energized position for the first and last terminal and in their energized position for the center terminal. When any TTD relay is energized, the path is looped via the NNE 1000 at that point.

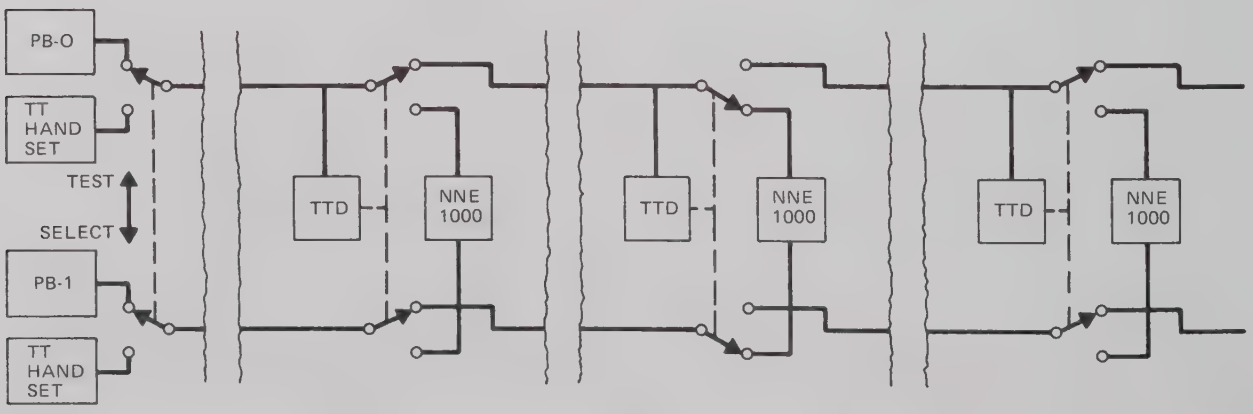
The representation is functional only, the NNE operates at the correct TLP's and impedances as specified by the customer. The straight-through connection, i.e., relay unenergized, must also be correctly matched. This latter matching is the customer's responsibility.

System control is via a touch tone send handset and a receive handset. Set up is verified by listening to the receive handset while manipulating the send handset keys as described below. The handsets, the TEST/SELECT switching, and control line access are provided by the customer.

Loopback at a specific location is established by

1. Placing the TEST/SELECT switch in a select position.
2. Sending the release code, *, while listening to the receive handset. If a loopback had been established at some location the receive handset will hear the release tone code momentarily, until the loop is dropped, after which there will be silence. A silent period of 1 second or more in duration will indicate that any loopbacks have been dropped.
3. Send the set up code for the desired looping point. After the set up delay, the receive handset will hear the set up tone code. A loopback connection has then then been established.

Thereafter testing may be accomplished using the NNE 1000 to separately examine the transmit and receive side of the facility from the central location to the designated loopback point. Sectionalization is accomplished by successively looping back at the remote locations in sequence and noticing when an impairment appears (or disappears).



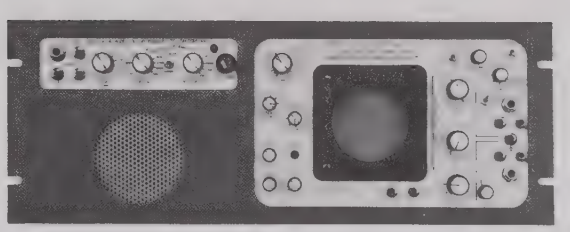
TEST EQUIPMENT

Many of the component impairments of notched noise listed on the second page are measured by conventional transmission measuring equipment, any of which may be used as the "TEST EQUIPMENT" referred to in the various block diagrams. The Bradley PB-1 measures all of the impairments listed and it is scaled in such a way that, in most cases, two steps on the range switch correspond to 5 to 1 (14 dB) ratio, one of the NOISE GAIN values. The PB-1 and PB-0 are described below.

THE MODEL PB-1 VOICE-FREQUENCY LINE ANALYZER IS A COMPACT, LIGHTWEIGHT, PORTABLE INSTRUMENT WHICH:

- Detects all disturbances, including types ignored by other instruments
- Provides comprehensive diagnostic capability
- Makes Go/No-Go evaluation of lines, using voice or data criteria

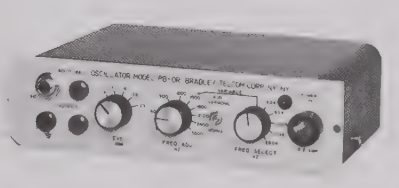
PB-1R — Rack Mounting VF Line Analyzer



Options available with either PB-1 or PB-1R

Hold coil option — 180 ohm hold coil, 2 Hy at 60 milliamperes. Switchable IN or OUT. Add $100.

Sixth frequency — A sixth operating frequency, between 300 and 3,000 Hz, may be designated by the customer. Add $100.



PB-OR

PB-O

The PB-O and PB-OR are station-quality oscillators despite their small size. They exhibit 1 Hz frequency accuracy, 0.2 dB level accuracy. Individual impairments in the output tone are in the -60 dB range. This is 20 dB below the normal "best telecommunication facility" which is to be examined using the oscillator as a test tone.

Frequency is either variable or switch selectable to those frequencies required for Bell System and CCITT gain slope measurements. These operating frequencies are the same for the PB-1 Line Analyzer. The output is switch selectable at six levels to accommodate the common Test Level Points.

The PB-O series oscillators also include an "ADD HARMONIC" mode in which -20 dB of second harmonic may be deliberately introduced. This feature permits examination of facilities for both frequency translation and for "Time Varying Phase Intercept Distortion" (See PB-1 data sheet), and for control of NNE-1000.

ORDERING INFO

Three functional variations of the NNE are available, as follows:

NNE 1000
NNE 1000R
NNE 1000 TTR

Also available is a transit case. The outside dimensions of this case are 7 1/4 x 8 1/4 x 12 3/4". It includes two cord pockets and is held closed by a strap rather than latches for shipping integrity.

Order – Transit case NNE

Other frequencies – The NNE units are avilable in an 800 Hz version in which case the "1000" in the designation becomes "800", i.e.,

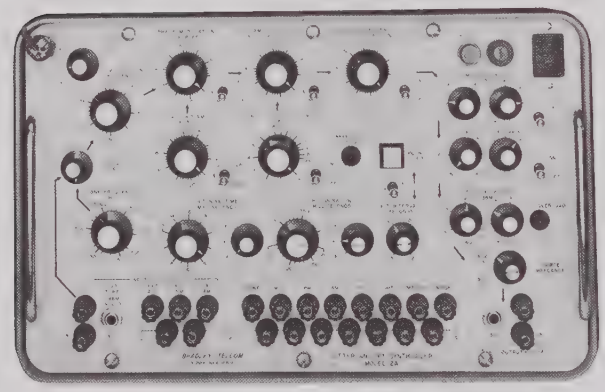
NNE 800
NNE 800R
NNE 800 TTR

Power line voltage

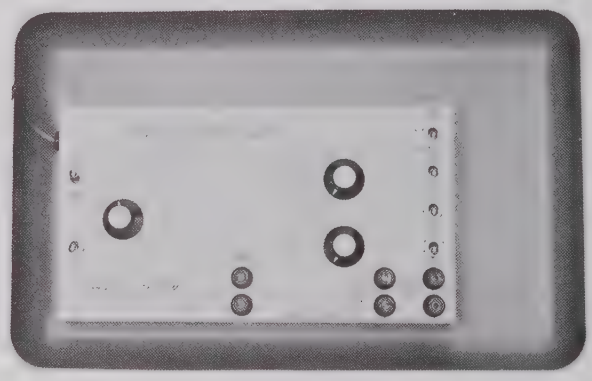
The standard unit operates at 50/60 Hz, 115 volts. For 230V 50/60 Hz operation, add E to designation. For 100 V 50/60 Hz, J. For example:

NNE 1000E	or	NNE 800E
NNE 1000RE		NNE 800RE
NNE 1000 TTRE		NNE 800 TTRE

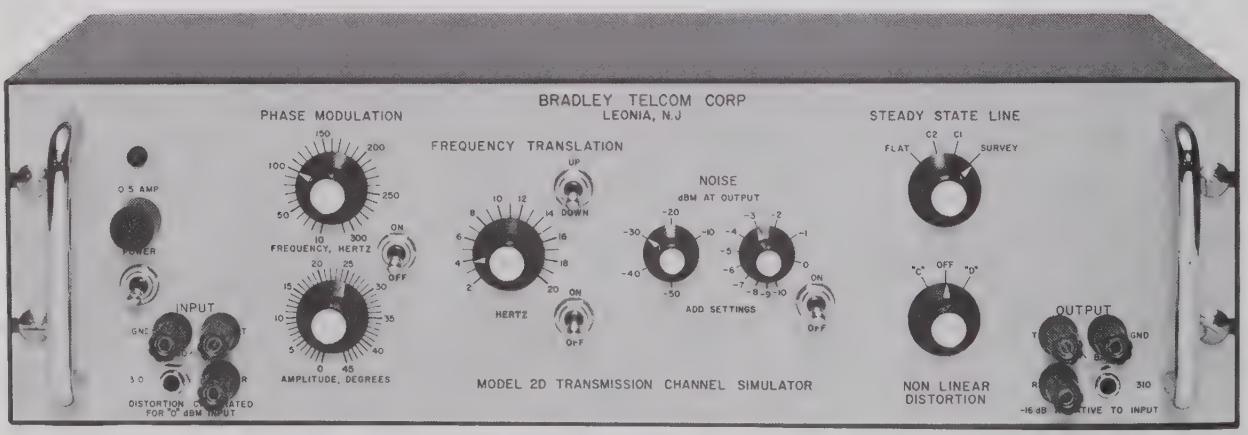
BRADLEY TELCOM ALSO MANUFACTURES LINE SIMULATORS, SEE BELOW



Model 2A Jitter and Hit Synthesizer



Model 2B Frequency Translation and Harmonic Distortion Module



Model 2D Modem Production Tester

SECTION III
THEORY OF OPERATION

3-1. GENERAL

The PB-1C-D contains an audio oscillator to provide various tones for testing voice-frequency transmission facilities, and the following circuits for measuring and displaying impairments induced on the test tones by those facilities: a suppressed-tone phasor-domain CRT display; a digital frequency meter; a digital multi-mode meter; a fast-reading LED-bar analog input-level meter; and a loudspeaker circuit. The theory of operation of those circuits is covered in this section.

3-2. OSCILLATOR CIRCUIT (Figure 3-1)

a. The oscillator employs integrating amplifiers AR1 and AR2 and inverting amplifier AR3, connected in a closed loop with an AGC circuit to maintain constant output level. The frequency of oscillation is determined by the RC time constants of the two integrators, which have equal input resistances and (not shown) equal feedback capacitances. Different operating frequencies are obtained by changing the pairs of input resistances. This is accomplished by means of the pushbutton-actuated three-section OSCILLATOR OUTPUT FREQUENCY switch, which has one section connected between AR3 and AR1, one section between AR1 and AR2, and one section between AR2 and AR3. The frequency-determining resistors are selected by the first and second switch sections, and the output of the oscillator is selected by the third switch section.

b. The OSCILLATOR OUTPUT FREQUENCY buttons are labeled 2000, 1000+2000, 1000, 2713, and VAR. They select the oscillator operating frequencies as follows:

1. The 2000, 1000 and 2713 buttons select pairs of fixed resistors giving actual oscillator frequencies of 2008, 1004, and 2713Hz, which can be adjusted precisely by means of trim potentiometers P3, P4, and P5 respectively, on the oscillator card.

2. The VAR button selects the 200 TO 5000Hz panel control (P1, a two-gang, ten-turn potentiometer), which permits varying the oscillator frequency over the designated range.

3. When the 1000+2000 button is depressed, the tone at the output section of the switch is 1004Hz with 31.6% second harmonic (i.e., 2008Hz 10dB down from the 1004Hz tone). The 1000+2000 button selects the same pair of fixed resistors as the 1000 button, so that the actual oscillator frequency is 1004Hz, which appears at the output section of the switch. At the 1004Hz oscillator frequency, a frequency doubler driven by inverter AR3 generates 2008Hz, which is fed through a 2008Hz low-pass filter and amplifier to the output section of the switch, where it is added to the 1004Hz tone. The level of the 2008Hz tone (31.6% of the 1004Hz tone, or −10dB relative to the 1004Hz tone) is set precisely by means of trim potentiometer P6.

c. In normal operation, the oscillator output is fed from the third switch section through amplifier AR7A, the OUTPUT LEVEL potentiometer and amplifier AR7B (all on the oscillator card), and through amplifier AR2A and an output transformer (both on the mother board) to the 310 OUTPUT jack. The secondary of the output transformer has dc blocking capacitors and series resistors to present a balanced 600-ohm output impedance at the jack.

d. External control of the oscillator is achieved through pins 17, 10, 11, and 9 of the PB-1C-D rear connector, which feed control terminals 12, 6, 5, and 13 respectively of the four independent solid-state switches contained in device U1 on the oscillator card. The solid-state switches are operated by ±5Vdc logic signals; the switches are open when their control terminals are at −5Vdc, and are closed when their control terminals are at +5Vdc.

1. Control terminal 13 (connected to rear connector pin 9) is tied to +5Vdc through a pull-up resistor, so that switch terminals 1-2 are normally closed; and control terminals 12, 6, and 5 are tied to −5Vdc through pull-down resistors, so that switch terminals 10-11, 8-9, and 3-4 are normally open. Thus, when there are no logic-level voltages supplied to rear connector pins 17, 10, 11, or 9, the oscillator is operating normally, as described in c. above.

2. When −5Vdc is fed (through rear connector pin 9) to U1 control terminal 13, it overcomes the +5Vdc pull-up voltage at that terminal and opens U1 switch terminals 1-2. The oscillator output at the third OSCILLATOR OUTPUT FREQUENCY switch section is thus disconnected from the input of amplifier AR7A.

3. If, while U1 switch terminals 1-2 are open, +5Vdc is fed (through rear connector pin 11) to U1 control terminal 5, it overcomes the −5Vdc pull-down voltage at that terminal, closing U1 switch terminals 3-4, and feeding 1004Hz + 31.6% 2008Hz through amplifiers AR7A, AR7B, etc., to the OUTPUT jack.

4. If, while U1 switch terminals 1-2 are open, +5Vdc is fed (through rear connector pin 10) to U1 control terminal 6, it overcomes the −5Vdc pull-down voltage at that terminal, closing U1 switch terminals 8-9 and feeding 2008Hz through amplifiers AR7A, AR7B, etc., to the OUTPUT jack.

5. If, while U1 switch terminals 1-2 are open, +5Vdc is fed (through rear connector terminal 21) to U1 control terminal 12, it overcomes the −5Vdc pull-down voltage at that terminal, closing U1 switch terminals 10-11 and permitting any external audio input in the 200 to 5000Hz range to be fed through rear connector pin 5 and through amplifiers AR7A, AR7B, etc. to the OUTPUT jack. *The external input signal voltage must not exceed absolute limits of ±4Vdc.*

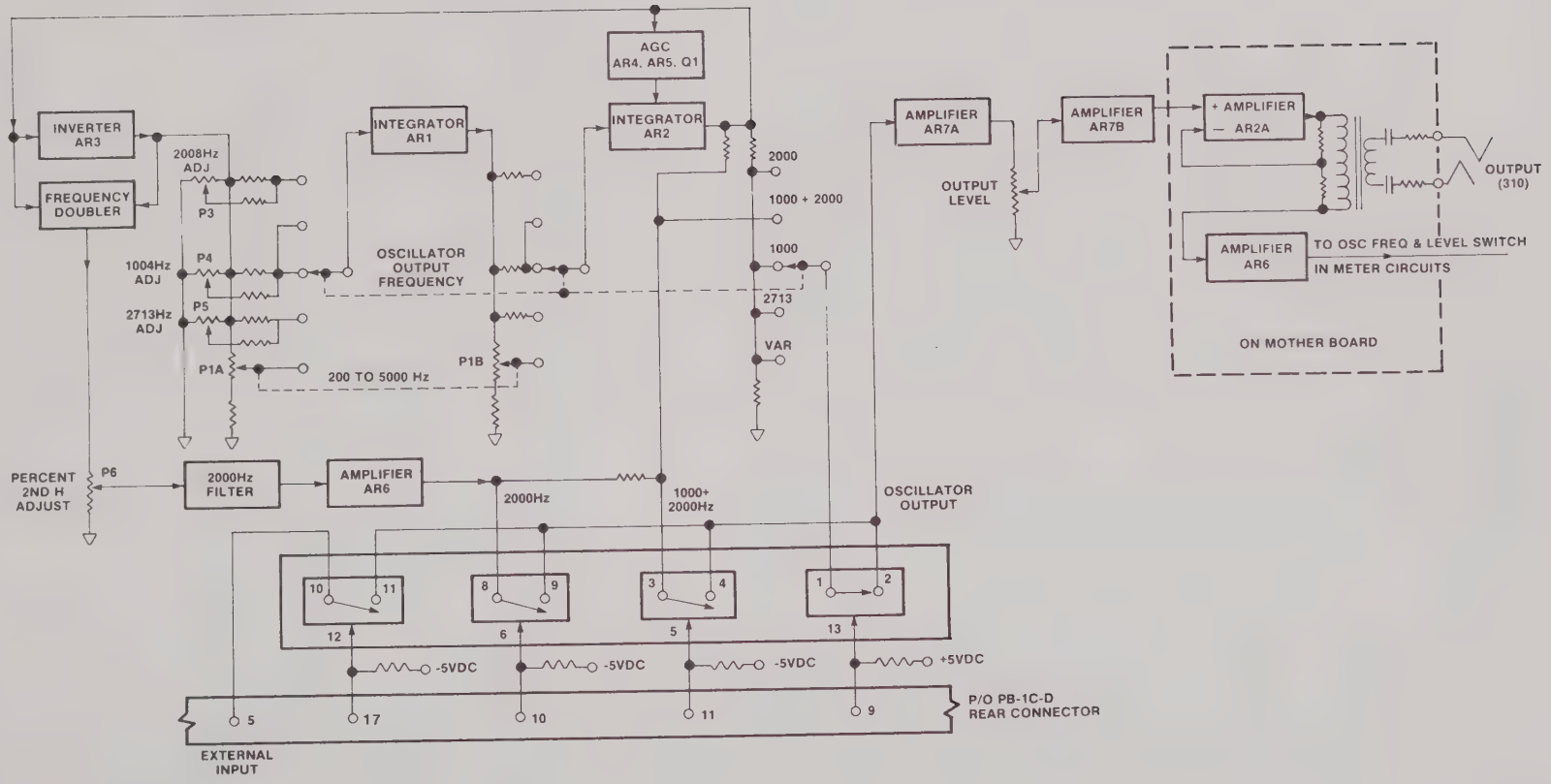


FIGURE 3-1 OSCILLATOR, SIMPLIFIED FUNCTIONAL DIAGRAM

6. NOTE: Since the four solid-state switches in U1 are independent, it is possible to close two or more at the same time unless that is prevented by external logic.

3-3. INPUT CIRCUIT (Figure 3-2)

a. The input circuit is common to all the measuring circuits in the PB-1C-D. The input signal to be analyzed is patched to the 310 INPUT jack, which is connected through dc-blocking capacitors to the primary of the input transformer. The input signals may be balanced or unbalanced. A HOLD COIL switch and a 600Ω/BRIDGE switch across the INPUT jack permit various terminations of the incoming line. When the HOLD COIL switch is set to IN, it connects across the INPUT jack a holding coil having a dc resistance of 180 ohms and inductances of 2 henries at 60mAdc and 1.3 henries at 100mAdc. When the 600Ω/BRIDGE switch is set to 600Ω, it connects across the INPUT jack a 600 ohm resistor rated to withstand a 48Vdc central office battery. When the 600Ω/BRIDGE switch is set to BRIDGE, the INPUT jack presents to the input line an impedance which is greater than 40 kilohms when the HOLD COIL switch is set to OUT, but which is reduced by the parallel impedance of the holding coil when the HOLD COIL switch is set to IN.

b. The secondary of the input transformer feeds an input amplifier, the output of which (called the input repeat) is fed to a 210Hz high pass filter, the AGC amplifier of the phasor-domain circuits, the fast INPUT LEVEL meter, the multi-mode meter, the frequency meter, the speaker circuit, the INTERCONNECT B jack, and the rear connector. All of these circuits are discussed in the following paragraphs.

3-4. PHASOR-DOMAIN CIRCUITS (Figure 3-2)

a. When a received signal comprising a quiet tone ($V_r\cos\omega t$) plus impairments is fed to the input of a suppressed-tone phasor-domain instrument such as the PB-1C-D, that instrument: (1) tracks the frequency and (2) normalizes the amplitude of the quiet tone in the received signal; (3) eliminates the quiet tone from the signal, leaving only normalized notched noise (NNN); resolves the normalized notched noise into in-phase and quadrature components which it (5) displays on a cathode-ray tube so that they can be separately identified and measured by means of calibrated scales on the CRT graticule.

b. The block diagram of Figure 3-2 shows how the suppressed-tone phasor-domain method is implemented by means of two high-gain closed loops, an automatic gain control (AGC) loop and a notch phase-lock loop (NPLL), which are interconnected to operate as a narrow-band notch filter that automatically tracks and suppresses the steady-state or quiet-tone component of the received signal.

c. The NPLL tracks the frequency of the quiet tone in the received signal and generates two orthogonal reference tones; one in phase with the quiet tone, and one in quadrature with the quiet tone.

d. In any of the four VECTOR NOTCH modes, the AGC loop normalizes the level of the received signal by amplifying the quiet tone in that signal to the same level as that of the in-phase reference tone from the NPLL.

e. Since the normalized quiet tone from the AGC amplifier is of the same phase and amplitude as the in-phase reference tone from the NPLL, the in-phase reference tone is equivalent to the normalized quiet tone and may be subtracted from the normalized received signal in a difference amplifier, leaving only normalized notched noise, NNN (i.e., normalized received signal minus quiet tone) containing all of the normalized impairments. This is equivalent to eliminating the quiet tone by means of an extremely narrow notch filter, but has the advantages that (1) it automatically follows or tracks variations in the frequency of the quiet tone, and (2) it maintains exactly the phase of each impairment with respect to the quiet tone, even after the quiet tone is suppressed.

3-5. Notch Phase-Lock Loop, NPLL (Figure 3-2)

a. The normalized input signal ($V_r\cos\omega t$ + impairments) from the AGC amplifier is fed to the NPLL, which locks to the normalized quiet tone ($V_r\cos\omega t$) and generates two synchronous reference-level sinusoidal outputs; one ($V_{ref}\cos\omega t$) in phase with the normalized quiet tone, and one ($V_{ref}\sin\omega t$) in quadrature with the normalized quiet tone.

b. The in-phase output ($V_{ref}\cos\omega t$) of the NPLL is fed to the (−) input of the difference amplifier, to one input of the AGC multiplier, and to the tip of the INTERCONNECT A jack, where it is designated the 'local oscillator' output.

c. The quadrature output ($V_{ref}\sin\omega t$) of the NPLL is used to feed one input of the display phase-lock loop (DPLL).

3-6. Automatic Gain Control (AGC) Loop (Figure 3-2)

a. The AGC Loop comprises an AGC amplifier, difference amplifier, AGC multiplier, and AGC integrator.

b. The received signal, containing the quiet tone $V_r\cos\omega t$ plus the impairments induced by the facility, is fed to the AGC amplifier, the gain of which is controlled so as to normalize the input signal by amplifying it until the level of the quiet tone $V_r\cos\omega t$ is equal to the level of the in-phase reference tone $V_{ref}\cos\omega t$ from the NPLL. The normalized quiet tone and its impairments, which are normalized along with the quiet tone, are fed to the NPLL and to the (+) input of the difference amplifier.

c. As stated in Par. 3-5, the NPLL locks to the quiet tone $V_r\cos\omega t$ in the normalized signal, and generates the in-phase reference tone $V_{ref}\cos\omega t$ and the quadrature reference tone $V_{ref}\sin\omega t$. The in-phase reference tone $V_{ref}\cos\omega t$ is fed to the (−) input of the difference amplifier and to one input of the AGC multiplier.

d. Since the (+) input to the difference amplifier is the normalized signal ($V_r\cos\omega t$ + impairments), and the (−) input is the in-phase reference tone from the NPLL, the output of the difference amplifier will be

($V_r\cos\omega t$ + impairments) − $V_{ref}\cos\omega t$, or (eq. 3-1a)
($V_r\cos\omega t$ − $V_{ref}\cos\omega t$) + impairments, or (eq. 3-1b)
($V_r - V_{ref}$) $\cos\omega t$ + impairments (eq. 3-1c)

e. Equations 3-1 show the following:

1. If the quiet tone $V_r\cos\omega t$ in the AGC amplifier

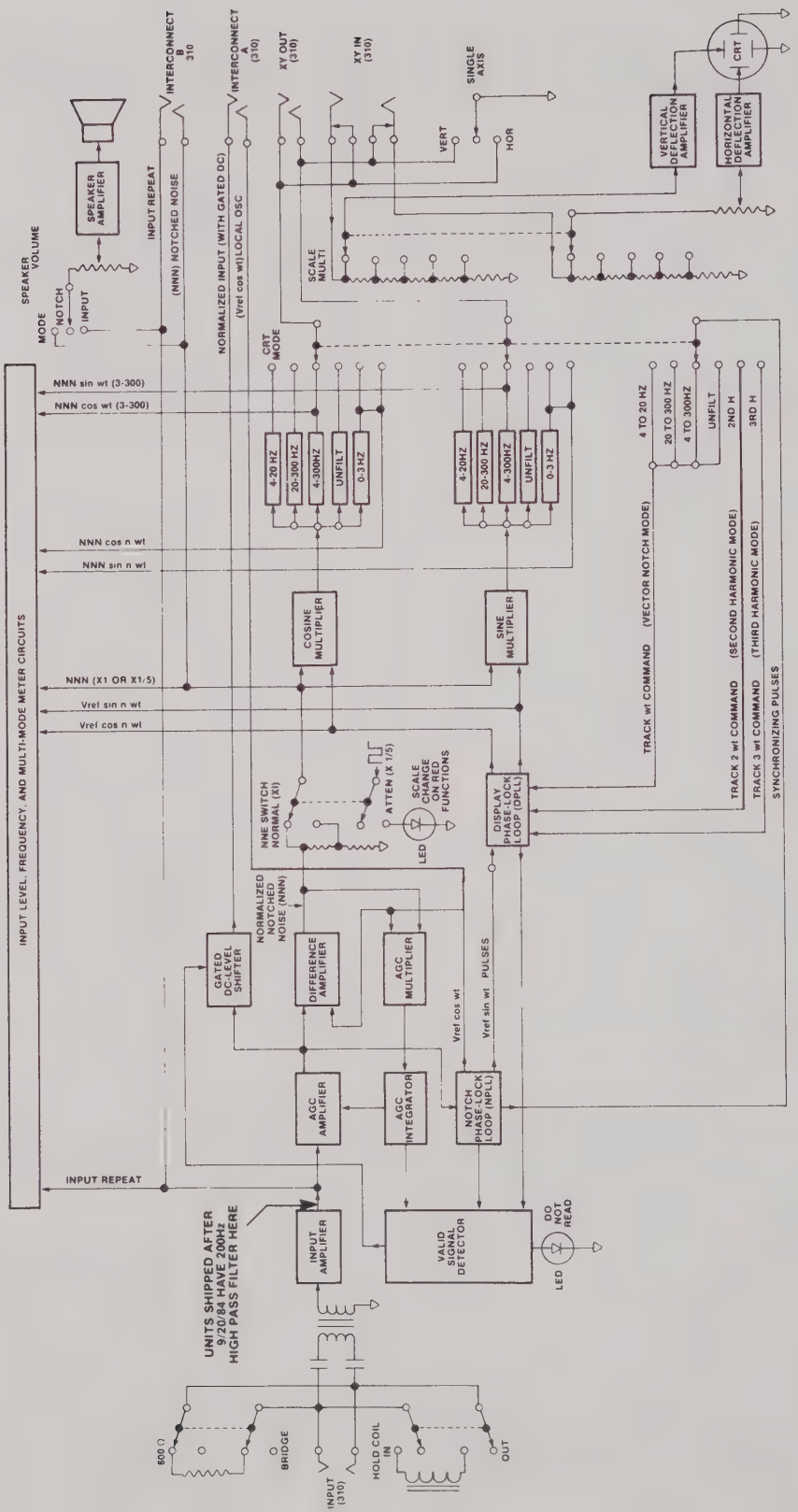


FIGURE 3-2 SIMPLIFIED FUNCTIONAL DIAGRAM, PB-1C-D CRT AND SPEAKER CIRCUITS

output is not equal to the in-phase reference tone $V_{ref}\cos \omega t$ from the NPLL, the difference amplifier output will contain the residual tone $(V_r - V_{ref})\cos \omega t$, plus impairments.

2. If the quiet tone $V_r\cos \omega t$ is equal to the in-phase reference tone $V_{ref}\cos \omega t$, the residual tone $(V_r - V_{ref})\cos \omega t$ will become zero and the output of the difference amplifier will contain only the impairments. Since the entire received signal ($V_r\cos \omega t$ + impairments) has been normalized in the process of amplifying the quiet tone $V_r\cos \omega t$ to exactly the same level as that of the in-phase reference tone $V_{ref}\cos \omega t$, the impairments or 'notched noise' remaining after the quiet tone has been removed, may be called **normalized notched noise** (NNN).

f. The difference output amplifier voltage, $(V_r - V_{ref})\cos \omega t$ + impairments, is fed to one input of the AGC multiplier; and the in-phase reference tone $V_{ref}\cos \omega t$ from the NPLL is fed to the other input. The output of the AGC multiplier is the product of its two inputs. Since the in-phase reference input $V_{ref}\cos \omega t$ from the NPLL is at a constant level, the AGC multiplier output will depend on the level of the residual tone $(V_r - V_{ref})\cos \omega t$ in the other AGC multiplier input, as follows:

1. If the residual tone $(V_r - V_{ref})\cos \omega t$ is equal to zero, the AGC multiplier output is the in-phase component of normalized notched noise, or NNN$\cos \omega t$.

2. If the residual tone $(V_r - V_{ref})\cos \omega t$ is not equal to zero, the output of the AGC multiplier will contain, in addition to the NNN$\cos \omega t$ voltage, a $(\cos \omega t)^2$ term. From the trigonometric identity,

$$(\cos \omega t)^2 = \tfrac{1}{2} + \tfrac{1}{2}\cos 2\omega t, \qquad \text{(eq. 3-2)}$$

it can be seen that the $(\cos \omega t)^2$ term comprises a dc component and an ac component at twice the frequency of the quiet tone.

g. The output of the AGC multiplier is fed to the AGC integrator, which filters out the ac component and integrates the dc component. The integrated dc output of the AGC integrator is used as the AGC control voltage, which varies the gain of the AGC amplifier until the dc component in the output of the AGC multiplier becomes zero. This occurs when the normalized quiet tone $V_r\cos \omega t$ in the AGC amplifier output is exactly equal in amplitude to the in-phase reference tone $V_{ref}\cos \omega t$ from the NPLL, so that the residual tone $(V_r - V_{ref})\cos \omega t$ in the output of the difference amplifier becomes zero, leaving only normalized notched noise, NNN, in the output of the difference amplifier.

3-7. Display Phase-Lock Loop, DPLL

a. The quadrature output $V_{ref}\sin \omega t$ of the NPLL is used to synchronize the DPLL. Depending on the setting of the CRT MODE buttons, the DPLL is commanded to phase-lock to the 1004Hz tone (when any one of the four CRT MODE VECTOR NOTCH buttons is depressed), to the 2008Hz second harmonic of the tone (when the CRT MODE 2ND H button is depressed), or to the 3012Hz third harmonic of the tone (when the CRT MODE 3RD H button is depressed).

b. If the DPLL is locked to the tone, its outputs are $V_{ref}\cos \omega t$ and $V_{ref}\sin \omega t$; if it is locked to the second harmonic of the tone, its outputs are $V_{ref}\cos 2\omega t$ and $_{ref}\sin 2\omega t$; and if it is locked to the third harmonic of the tone, its outputs are $V_{ref}\cos 3\omega t$ and $V_{ref}\sin 3\omega t$.

3-8. Valid Signal Detector and DO NOT READ Indicator

In order for a test tone to be monitored by the phasor-domain circuits, the AGC amplifier must be tracking and normalizing the level of the quiet tone in the received signal, the NPLL must be tracking the frequency of the quiet tone, and the DPLL must be tracking the NPLL. These three conditions are sensed by the valid signal detector. If the quiet tone level is between −40 and +10dBm, the quiet tone frequency is between 930 and 1030Hz, and the above three conditions are met, the DO NOT READ indicator will be off. If any one or more of the three conditions is not met, the valid signal detector will: (1) turn on the DO NOT READ indicator; (2) gate the dc level shifter which feeds the normalized input to the ring of the INTERCONNECT B jack; and (3) pull the CRT trace down off the screen.

3-9. NNE Switch

a. The normalized notched noise (NNN) voltage at the output of the difference amplifier is fed through the NNE switch to one input each of the cosine and sine multipliers, to the multimode meter circuit, to the speaker circuit, and to the tip of the interconnect B jack.

b. In the NORMAL position of the NNE switch the full NNN voltage from the difference amplifier is fed to the locations listed in a. above.

c. In the ATTEN position of the NNE switch, the NNE voltage from the difference amplifier is attenuated by a factor of 5, to a level of −14dB relative to the NORMAL level, before being fed to the locations listed in a. above. The ATTEN position of the NNE switch is intended for use only when the input to the PB-1C-D is the output of a remote NNE-1000 Transparent Line Generator. The notched noise enhancement factor of a TLG is X5 or +14dB, so that when the NNE switch is in the ATTEN position, the enhanced notched noise received from the remote NNE-1000 is attenuated by a factor equal to the notched noise enhancement factor. The NNN level being measured at the locations listed in a. above is thus equal to the NNN level at the input to the remote TLG.

d. To remind the operator that the NNE switch has been set to ATTEN, a second pole of the switch feeds a square-wave voltage to the SCALE CHANGE ON RED FUNCTIONS indicator, which thus flashes when the NNE switch is in the ATTEN position.

3-10. Cosine And Sine Multipliers

a. The normalized notched noise (NNN) voltage from the difference amplifier is fed through the NNE switch to one input of the cosine multiplier and to one input of the sine multiplier.

b. The cosine (in-phase) output of the DPLL is fed to the second input of the cosine multiplier, and the sine (quadrature) output of the DPLL is fed to the second input of the sine multiplier. The frequency of the DPLL outputs is ω, 2ω, or 3ω, depending on the CRT MODE switch.

c. The CRT MODE switch has three sections; one selects the DPLL operating frequency, and the remaining two select the bandwidths of the outputs of the cosine and sine multipliers.

1. In any VECTOR NOTCH position of the CRT MODE switch, one section of the switch commands the DPLL to track the tone frequency ω, so that the outputs of the cosine and sine multipliers are NNNcos ωt and NNNsin ωt respectively. In the 4 TO 20, 20 TO 300, 4 TO 300, and UNFILTered VECTOR NOTCH positions, the remaining sections of the CRT MODE switch pass the NNNcos ωt and NNNsin ωt voltages through filters of the designated bandwidths (the UNFILT position passes the full voice-frequency band).

2. In the 2ND H position of the CRT MODE switch, one section of the switch commands the DPLL to track at twice the tone frequency so that the outputs of the cosine and sine multipliers are NNNcos $2\omega t$ and NNNsin $2\omega t$ respectively. The remaining sections of the CRT MODE switch pass the NNNcos $2\omega t$ and NNNsin $2\omega t$ voltages through 0 to 3Hz low-pass filters.

3. In the 3RD H position of the CRT MODE switch, one section commands the DPLL to track at three times the tone frequency, so that the outputs of the cosine and sine multipliers are NNNcos $3\omega t$ and NNNsin $3\omega t$ respectively. The remaining sections of the CRT MODE switch pass the NNNcos $3\omega t$ and NNNsin $3\omega t$ voltages through the same 0 to 3Hz low-pass filters as in the 2ND H mode.

3-11. CRT Display Circuits

a. The cosine and sine multiplier outputs having the center frequencies and bandwidths selected by the CRT MODE switch, are fed to the XY OUT and XY IN jacks and the SINGLE AXIS switch, and through the transfer contacts of the XY IN jack to the SCALE MULT switch which feeds the CRT vertical and horizontal deflection amplifiers.

b. The XY OUT Jack makes available for external recording, measurement or display, the voltages at the inputs of the SCALE MULT switch that feeds the CRT vertical and horizontal deflection amplifiers. The tip voltage is that at the input to the SCALE MULT switch section which feeds the horizontal deflection amplifier, and the ring voltage is that at the input to the SCALE MULT switch section which feeds the vertical deflection amplifier. The amplitudes of these voltages are not affected by the settings of the SCALE MULT switch.

c. The XY IN Jack is a transfer jack that permits the PB-1C-D to be used as an X-Y oscilloscope or 'vectorscope' to display modem 'eye patterns', 'constellation patterns', or 'decision spaces'. Many modems have X-Y outputs for this purpose.

1. When the XY IN jack is not used, the outputs of the phasor domain circuits (which are derived from the received signal at the INPUT jack) are fed to the inputs of the CRT vertical and horizontal deflection amplifiers.

2. When a patch cord is plugged into the XY IN jack the outputs of the phasor domain circuits are disconnected from the inputs of the CRT deflection amplifiers, the patch cord tip is connected to the input of the horizontal (or X) deflection amplifier, the patch cord ring is connected to the input of the vertical (or Y) deflection amplifier, and the patch cord sleeve is connected to the PC-1C-D ground. The CRT display is then that of an X-Y oscilloscope or vectorscope. Both X and Y inputs have the same nominal deflection sensitivities, which are related to the SCALE MULT switch settings by the table in Par. 2-17b.

3. Since both the X and Y inputs are single-ended, it is necessary to interconnect the grounds of the PB-1C-D and of the source at the other end of the patch cord. The XY In jack sleeve is connected to the PB-1C-D ground; if the source jack sleeve is connected to the source ground, it is merely necessary to interconnect the two sleeves (i.e., through the third wire of a three-wire patch cord). However if the PB-1C-D and the source are connected to the same power line ground, no further ground interconnection is necessary.

d. The SINGLE AXIS switch is a three-position toggle switch with spring return to the center position from either the upper (VERT) or lower (HOR) positions. In the center position, the horizontal signal is fed to the CRT horizontal amplifier and the vertical signal is fed to the CRT vertical amplifier, so that the CRT spot can be deflected over the entire screen. In the VERT position, the input to the horizontal amplifier is grounded so that only vertical deflection is possible. This aids measurement of amplitude jitter on the CRT in the VECTOR NOTCH modes. In the HOR position, the input to the vertical amplifier is grounded so that only horizontal deflection is possible. This aids measurement of phase jitter on the CRT in the VECTOR NOTCH modes.

e. SCALE MULT Switch. The CRT display sensitivity is determined by the five SCALE MULT pushbuttons. Each button is labeled with the factor that the horizontal and vertical scales must be multiplied by, and with the number of dB that must be added to or subtracted from the polar scale, when that button is depressed. The corresponding HOR/VERT and polar scale modifiers selected by the SCALE MULT pushbuttons are tabulated in Par. 2-15. The following paragraphs show how the SCALE MULT buttons change the values read on the horizontal, vertical, and polar scales.

1. The horizontal scale on the graticule is numbered $\pm(1,2,3)$, and the vertical scale is numbered $\pm(2,4,6)$. The horizontal scale represents angular degrees, and the vertical scale represents percent change. Although the horizontal and vertical scales represent different units, the same SCALE MULT switch HOR/VERT multiplication factors apply to both simultaneously, as shown by the table in Par. 2-15a.

2. Phenomena such as gain hits and gain steps are displayed as vertical deflections in percent, but are customarily referred to in dB relative to the tone amplitude. Figure 2-4 is a plot of the relationship between percent change and dB change.

3. The graticule circles used for the polar dB scales are numbered -10, -12, -14, -16, -20, from the outside in. The innermost (-30dB) circle is not numbered. Since the calibrations of the circles represent dB relative to the dB setting of the SCALE MULT switch, the dB value at each setting of the SCALE MULT switch must be added algebraically to the graticule circle values. The table in Par. 2-15c shows how the dB setting and the graticule reading are added to give the total level in dB of any deflection.

3-12. SPEAKER CIRCUIT (See Figure 3-2)

a. The speaker circuit comprises a three-position SPEAKER MODE switch, SPEAKER VOLUME control, speaker amplifier AR5, and a loudspeaker. In its two end positions, the SPEAKER MODE switch connects the SPEAKER VOLUME control to the normalized NOTCHed noise voltage or to the INPUT repeat voltage; a center-off position permits turning off the audio output without changing the setting of the SPEAKER VOLUME control. The SPEAKER VOLUME control adjusts the level of the voltage fed to the speaker amplifier. The output of the speaker amplifier is fed to the loudspeaker.

b. The maximum gain of the speaker circuit (i.e., with the SPEAKER VOLUME control set at its cw stop) is sufficient to amplify weak input or notched noise voltages to audible levels; but will cause saturation and distortion on strong signals, producing highly audible multiple harmonics in the acoustic output. Such harmonics can be eliminated by reducing the setting of the SPEAKER VOLUME control when strong signals are received.

3-13. METER CIRCUITS

There are three meter displays; the frequency meter, the fast INPUT LEVEL meter and the multi-mode meter. The frequency meter employs the dedicated circuit described in Par. 3-14, and the fast INPUT LEVEL meter employs the dedicated circuit described in Par. 3-15. The multi-mode meter has five major operating modes, each employing a circuit selected by the METER MODE LEVEL, NOISE, NN SEP, AMPL. JITTER and PHASE JITTER buttons; and two harmonic separation modes, each employing a circuit selected by the HARMONIC SEPARATION button and the 2ND H or 3RD H CRT MODE buttons. The multi-mode meter circuits are described in Par. 3-16ff.

3-14. FREQUENCY METER (Figure 3-3)

a. The frequency meter can measure the frequency of any one of three different voltages, as follows:

1. The input repeat voltage is the normal input to the frequency meter.

2. The oscillator output voltage is selected as the input to the frequency meter when the OSC FREQ & LEVEL button is depressed.

b. The frequency meter contains a crystal oscillator that generates 32761.45Hz clock pulses which are used to develop gate, store and reset pulses, as follows:

1. The 32761.45Hz clock pulses are fed to a 2^{-16} frequency divider and an and circuit. The output of the frequency divider is a 500,000 microsecond gate pulse, which is fed to a gate circuit and a differentiator.

2. The differentiator output is a 50 microsecond store pulse, the leading edge of which is coincident with the trailing edge of the 500,000 microsecond gate pulse. The 50 microsecond store pulse is fed to a storage register display driver, and to one-shot multivibrator MV2.

3. The output of one-shot multivibrator MV2 is a 50 microsecond reset 1 pulse, the leading edge of which is coincident with the trailing edge of the store pulse. The reset 1 pulse is fed to the counter, and to the and circuit mentioned above.

c. The selected input of frequency f is amplified to a relatively constant level in a self-AGC'd amplifier, and fed through a frequency doubler to one-shot multivibrator MV1. Pulses at frequency 2f from MV1 are fed to the gate circuit, which is turned on for one-half second (during the 500,000 microsecond gate pulse) and turned off for 100 microseconds (during the 50 microsecond store pulse and the 50 microsecond reset 1 pulse). During the gate pulse the gate circuit is turned on so that it transmits f pulses (= 0.5 second × 2f pulses per second) to the counter, and during the store and reset 1 pulses the gate circuit is turned off, so that it transmits no pulses to the counter. The counter therefore counts to f during the gate pulse. At the end of the gate pulse the store pulse causes the storage register/display driver to store the count of f from the counter. After the store pulse, the reset 1 pulse resets the counter to zero so that it can begin counting again during the next gate pulse. The storage register/display driver cyclically transmits the stored count to the display.

3-15. FAST INPUT LEVEL METER (Figure 3-4)

a. The fast INPUT LEVEL meter employs two 10-bar LED displays in tandem to form a horizontal array in which successive bars are lit by 3dB changes in the analog input voltage. The left display covers the range −42 to −21dBm, and the right display covers the range −18 to +9dBm.

b. The input repeat voltage (see Figure 3-2) is fed through high-end adjustment P1 (on the mother board) to a fast detector. The rectified output of the fast detector is fed directly to display driver U1 which drives the right-hand display U3, and through a 30dB dc amplifier to display driver U2 which drives the left-hand display U4.

c. Each display driver has ten outputs, each of which is connected to one bar of the associated LED display. When any output is activated, it causes the corresponding LED to light. Only one output is activated at any time, so that only the corresponding LED bar is lit. At some minimum input voltage to a driver, the first (left-hand) bar is lit; and as the input voltage increases 3dB, the first bar is extinguished and the second bar is lit. As the input voltage continues to increase, the bars to the right light up at successive 3dB increments until, at the input voltage which is 27dB above the minimum voltage, the tenth (right-hand) bar is lit, and at the input voltage which is 30dB above the minimum voltage, the tenth bar is extinguished.

d. The input repeat voltage range over which display driver U1 and display U3 operate is −18 to +9dBm. To accommodate a lower range of input voltages, the 30dB dc amplifier is used. When the input repeat voltage is −42dBm, display driver U1 and display U3 are inoperative, but the 30dB amplifier raises the input voltage of display driver U2 to the level at which the LED labeled −42dBm on display U4 is lit. Note that the range from −42dBm to −21dBm uses only eight LEDs, and that the two LEDs at the left of display U4 are covered.

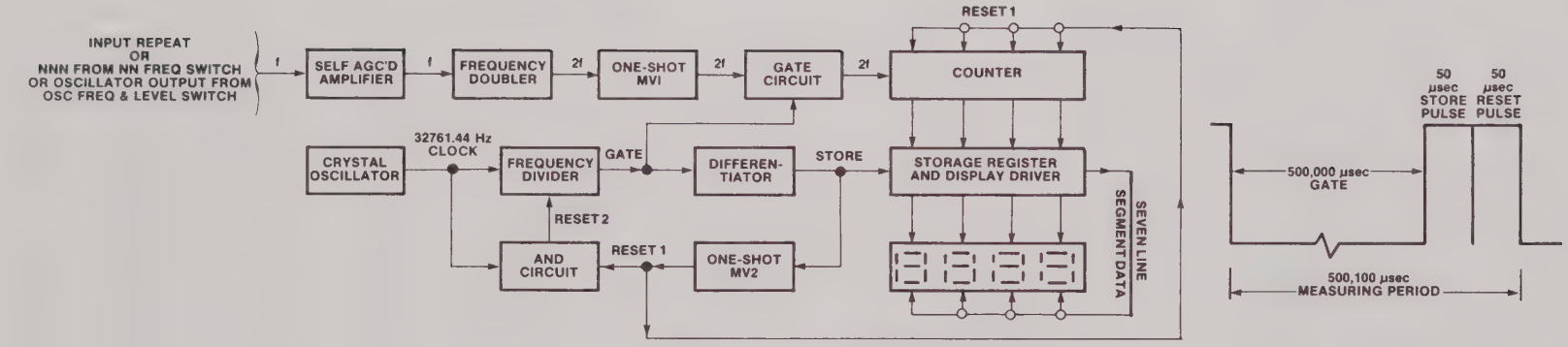


FIGURE 3-3. FREQUENCY METER CIRCUIT, SIMPLIFIED FUNCTIONAL DIAGRAM AND TIMING DIAGRAM

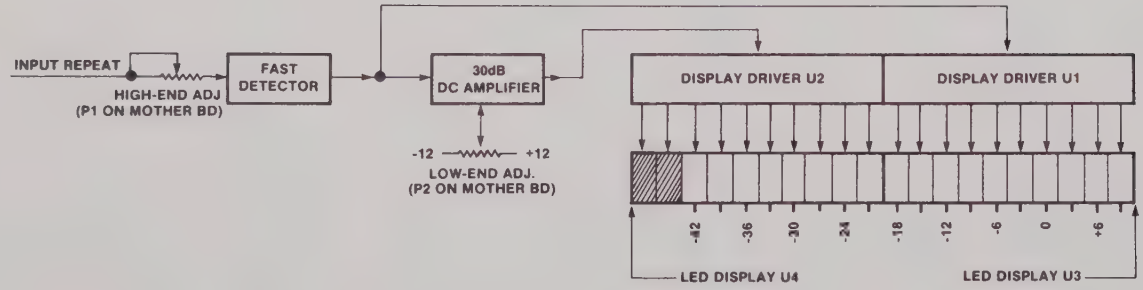


FIGURE 3-4 FAST INPUT LEVEL METER, SIMPLIFIED FUNCTIONAL DIAGRAM

3-16. MULTI-MODE METER (Figure 3-6)

a. As shown in Figure 3-2, the input voltages to the meter circuits are: input repeat; $V_{ref}\cos \omega t$ and $V_{ref}\sin \omega t$ from the display phase-lock loop; normalized notched noise (NNN) from the difference amplifier and NNE switch; NNN$\cos \omega t$ and NNN$\sin \omega t$; and NNN$\cos n\omega t$ and NNN$\sin n\omega t$, when $n = 2$ or 3. The voltage to be measured, and the appropriate measuring circuit, are selected mainly by the METER MODE buttons; but the selection can be overridden by the OSC FREQ & LEVEL and HARMONIC SEPARATION buttons.

b. The multi-mode meter employs a 3½-digit digital dc voltmeter with a basic range of −0.099V to 0.999V. Each of the signal voltages selected for measurement by the METER MODE buttons is weighted and detected in accordance with established specifications, and then processed to match the basic range of the digital voltmeter. Such processing may include one or more of the following: logarithmic conversion, inversion, and level-shifting. Where logarithmic conversion is required, the dB card described in Par. 3-17 is automatically connected into the multi-mode meter circuit. The linear modes (AMPL. JITTER and PHASE JITTER) of the multi-mode meter use the meter and display cards. The logarithmic modes (LEVEL, NOISE, NN SEP, 2ND HARMONIC SEPARATION, and 3RD HARMONIC SEPARATION), in which the displayed quantities are in dB, dBm, or dBrnC, use the dB meter and display cards.

3-17. dB Card (Figures 3-5, 3-6A, 3-6B, 3-6C, 3-6E)

a. The dB card is used whenever a logarithmic conversion is required, as in the LEVEL mode (Figure 3-6A), NOISE mode (Figure 3-6B), NN SEP mode (Figure 3-6c), and the 2ND H and 3RD H HARMONIC SEPARATION modes (Figure 3-6E).

b. As shown in Figure 3-5 the dB card input voltage selected in any of the logarithmic modes above is fed to absolute value detector AR2A/B, which develops a unipolar output voltage regardless of the input voltage polarity. The output of AR2A/B is fed to the (−) input of average detector AR1 and to the input of peak detector AR3A, which develops an output voltage equal to the maximum value of its input voltage. The output of peak detector AR3A is fed to the (+) input of average detector AR1 and to solid-state switch U3A.

1. In the LEVEL mode (Figure 3-6A), which employs average detection, solid-state switch U3A is closed, so that the (+) input of average detector AR1 is grounded. The only input to AR1 is then the output voltage from absolute value detector AR2A/B, so that the output of AR1 is the average of the absolute value of the input voltage to the dB card.

2. In the NOISE mode (Figure 3-6B), NN SEP mode (Figure 3-6C) or HARMONIC SEPARATION modes (Figure 3-6E), all of which employ quasi-rms detection, solid-state switch U1A at the output of AR3A is open, so that there are two inputs to AR1; the (−) input is the output voltage of absolute value detector AR2A/B, and the (+) input is the output voltage of peak detector AR3A. The output of AR1 is then the sum of the peak and average of the absolute value. This is defined as the quasi-rms value.

3. Since peak plus average values are greater than average values, quasi-rms (peak plus average) measurements would be greater than average measurements of the same quantities, unless some means is provided to equalize or match the two measurements. Adjustment P9 on the dB card permits matching quasi-rms and average measurements for single-frequency sine-wave inputs. P9 is connected across the output of AR1 through solid state switch U1A, and the voltage at the arm of P9 is fed back to the (−) input of AR1 so that the gain of AR1 is reduced by an amount dependent on the setting of P9 whenever switch U1A is closed. Switch U1A is open in the average-detecting LEVEL mode, and is closed in the quasi-rms (peak plus average) detecting NOISE, NN SEP, and HARMONIC SEPARATION modes, so that the gain of AR1 in the quasi-rms modes is less than in the average mode. Some setting of P9 can be found which, for a sine-wave input, will reduce the quasi-rms gain so that the outputs in the NOISE, NN SEP and HARMONIC SEPARATION modes are equal to the output in the LEVEL (average) mode.

c. The average or quasi-rms (peak plus average) output of AR1 is fed through solid-state switch U1D to logarithmic amplifier U6. The output of U6 is fed to correction amplifier AR5A/B which, through solid-state switch U3B, feeds sample/hold amplifier AR7.

d. Correction amplifier AR5A/B is designed to permit automatic correction of its 0dBm offset (the 'point' correction) and its −20dBm gain (the 'slope' correction) as follows:

1. A switching voltage source generates three pulses: a measure pulse (approximately 1 second), a 0dBm set pulse (approximately 20 milliseconds), and a −20dBm set pulse (approximately 20 milliseconds). As shown in the timing diagram of Figure 3-5, the three pulses are generated in the following sequence: measure; set 0dBm; measure; set −20dBm; etc. The circuit of Figure 3-5 is shown in the measure phase.

2. In the **set 0dBm** interval, a 0.7Vdc reference voltage is fed to log amp U6. The output of U6 is fed through correction amplifier AR5A/B to 0dBm integrator AR3B, and the output of AR3B is fed to the 0dBm offset correction input of AR5A/B, in the polarity that will reduce the 0dBm measurement error.

3. In the **set −20dBm** interval, a 0.07Vdc reference voltage is fed to U6, and the output of U6 is fed through AR5A/B to −20dBm integrator AR6. The output of AR6 is fed to the −20dBm correction input of AR5A/5B in the polarity that will reduce the −20dBm measurement error.

4. Sample/hold amplifier AR7 samples the output of amplifier AR5A/B during the one-second measuring intervals, and holds that output during the 20-millisecond **set 0dBm** and **set −20dBm** correction intervals.

3-18. LEVEL Mode (Figure 3-6A).

a. When the LEVEL button is depressed, the multi-mode meter measures the level in dBm of the average-detected input repeat voltage (see Figure 3-2) over the range −45 to +9.9dBm.

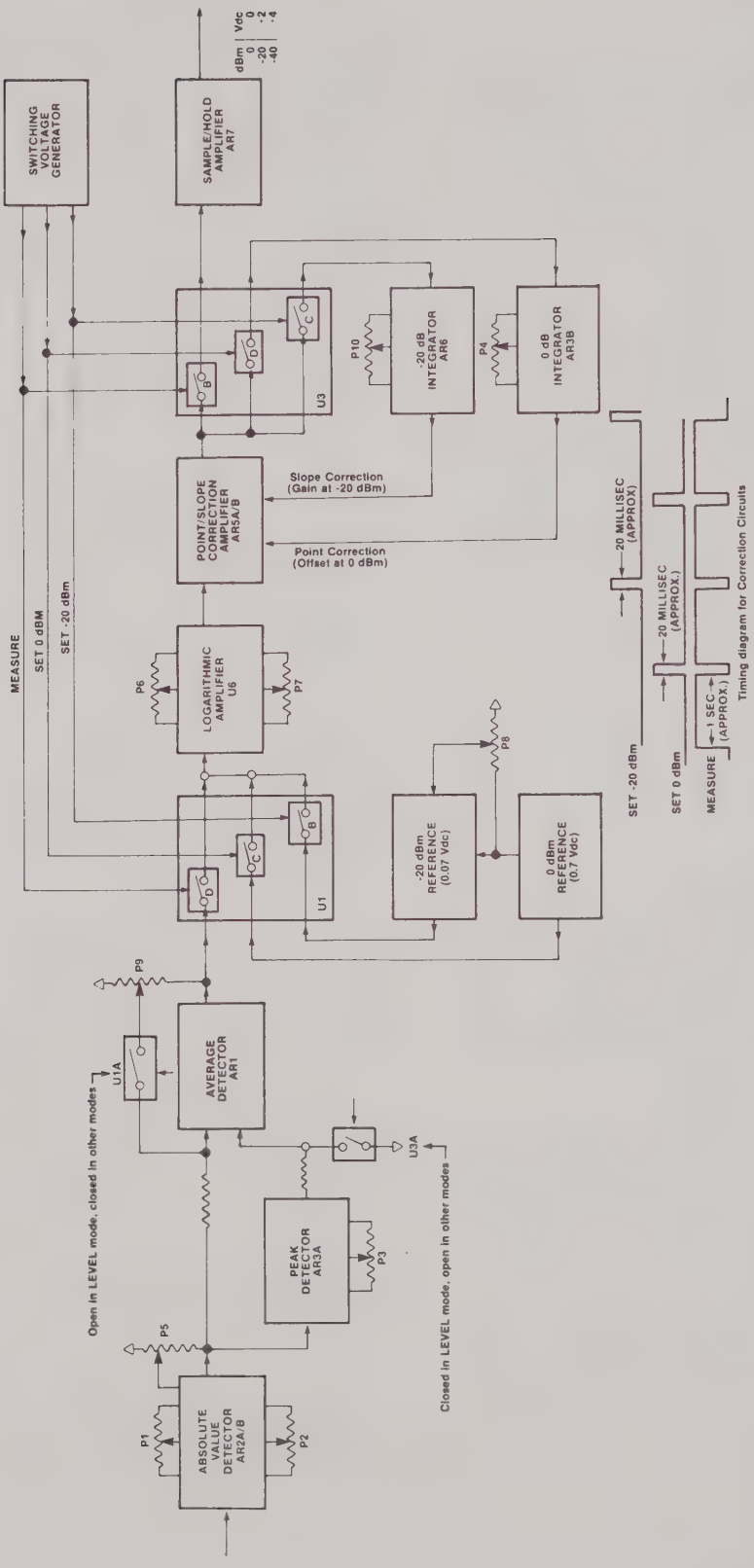


FIGURE 3-5 dB CARD, SIMPLIFIED FUNCTIONAL DIAGRAM

b. The input repeat voltage is fed through a 200Hz high-pass filter and the dB card to the digital voltmeter. The 200Hz high-pass filter attenuates input frequency components below 200Hz, including 60, 120 and 180Hz power-line pickup. If the power-line pickup is negligible, the REMOVE FILTER button may be depressed to short out the filter so that the input-frequency components below 200Hz are added to the measurement.

c. The output of the 200Hz high-pass filter is fed through the normally-closed contacts of the OUTPUT FREQ & LEVEL and HARMONIC SEPARATION buttons to the dB card which, in the LEVEL mode, is set for average detection.

d. The output of the dB card is fed to the digital voltmeter. The digital voltmeter input varies from +450mVdc at −45dBm to −99mVdc at +9.9dBm. A sign comparator circuit adds a minus sign to the display for input levels below 0dBm.

3-19. NOISE Mode (Figure 3-6B).

a. When the NOISE button is depressed, the multi-mode meter measures the level in dBrnC of the noise on the C-message-weighted and quasi-rms-detected input repeat voltage (see Figure 3-2) over the range 20 to 80dBrnC.

b. The input repeat voltage is fed through a 20dB amplifier and a C-message filter to the dB card. When the REMOVE FILTER button is depressed, the C-message filter is shorted out so the input frequency components attenuated by the C-message filter are added to the measurement. In this condition the readings will be in dBrn, and not in dBrnC, since the C-message weighting is removed.

c. The output of the C-message filter is fed through normally-closed contacts of the HARMONIC SEPARATION switch to the dB card which, in the NOISE mode, is set for quasi-rms detection.

d. The output of the dB card is fed through an inverting amplifier to the digital voltmeter. Adjustment P1 on the meter card biases the inverting amplifier so that the digital voltmeter input varies from −200mVdc at 20dBrnC to −800mVdc at 80dBrnC.

3-20. NN SEP Mode (Figure 3-6C)

a. When the NN SEP button is depressed, the multi-mode meter measures the separation in dB relative to tone of the C-message weighted, wide-band filtered, and quasi-rms detected normalized notched noise voltage NNN (see Figure 3-2) over the range −50 to 0dB.

b. Two notch band widths are provided. The tone is removed by a tracking notch of ±4Hz bandwidth. The AGC'd input is also filtered by a ±25Hz wide non-tracking notch. Page 0-3 WIDE NOTCH/NARROW NOTCH gives the justification for this. Bradley Telcom considers the wide notch a shoddy measurement practice but *illigitimus carborundum*.

c. The NNN voltage is fed through the wide-band notch filter, then through the C-message filter to the dB card. Depressing the REMOVE FILTER button shorts out the C-message filter so the NNN frequency components attenuated by the C-message filter are added to the measurement. Pressing the momentary NN SEP button removes the wide-band filter allowing the notch bandwidth to be controlled by the ±4Hz tracking notch.

d. The output of the C-message filter is fed through normally-closed contacts of the HARMONIC SEPARATION switch to the dB card which, in the NN SEP mode, is set for quasi-rms detection. The output of the dB card is added to the output of an inverter, and the sum is fed to the digital voltmeter. The input to the digital voltmeter is +500mVdc at −500mVdc at −50dB and 0mVdc at 0dB.

3-21. AMPL. JITTER Mode (Figure 3-6D)

a. When the AMPL. JITTER button is depressed, the multi-mode meter measures the peak-to-peak amplitude jitter in percent, of the (20-300Hz) filtered NNNcos ωt voltage, over the range 0 to 50%. Note that NNNcos ωt is the component of normalized notched noise in phase with the test tone.

b. The NNNcos ωt voltage is fed through an amplifier and a 20Hz high-pass filter to a peak-to-peak detector. The 20Hz filter attenuates amplitude jitter components below 20Hz. When the ADD LF button is depressed, the filter is shorted out and the amplitude jitter components below 20Hz are added to the measurement, and the measured bandwidth becomes (4-300Hz).

c. The output of the 20Hz high-pass filter is fed to the peak-to-peak detector. The output of the detector is fed through amplitude jitter scale adjustment P6 (on the meter card) to the digital voltmeter. P6 is set so that the input to the digital voltmeter ranges from −500mVdc at 50% amplitude jitter to 0mVdc at 0% amplitude jitter.

3-22. PHASE JITTER Mode (Figure 3-6D)

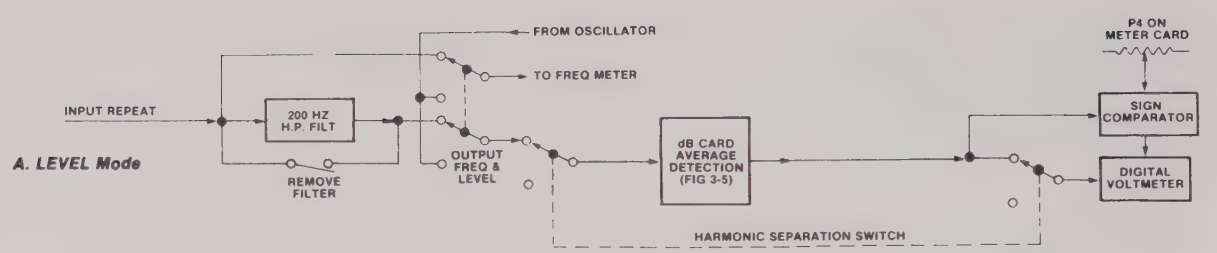
a. When the PHASE JITTER button is depressed, the multi-mode meter measures the peak-to-peak phase jitter in degrees, of the (20-300Hz) filtered NNNsin ωt voltage, over the range 0 to 50°. Note that NNNsin ωt is the component of normalized notched noise in quadrature with the test tone.

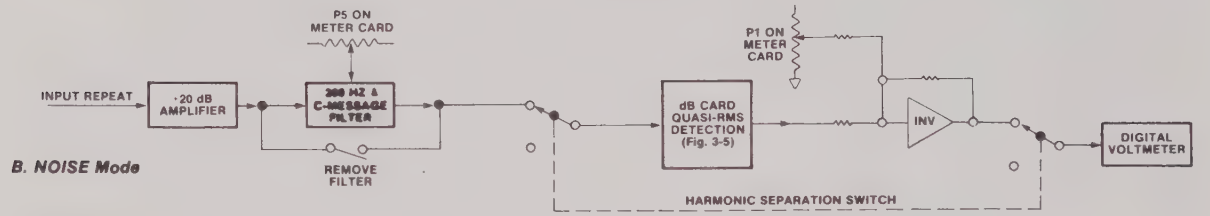
b. The NNNsin ωt voltage is fed through the 20Hz high-pass filter to the peak-to-peak detector. The 20Hz filter attenuates phase jitter components at frequencies below 20Hz. When the ADD LF button is depressed, the filter is shorted out and the phase jitter components below 20Hz are added to the measurement, so that the measured bandwidth becomes (4-300Hz).

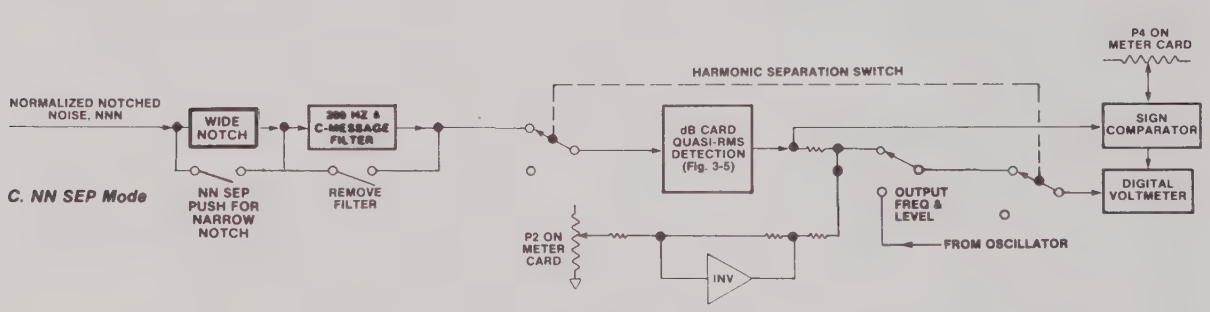
c. The output of the 20Hz high-pass filter is fed to the peak-to-peak detector. The output of the detector is fed through phase jitter scale adjustment P7 (on the meter card) to the digital voltmeter. P7 is set so that the input to the digital voltmeter ranges from −500mVdc at 50° phase jitter to 0mVdc at 0° phase jitter.

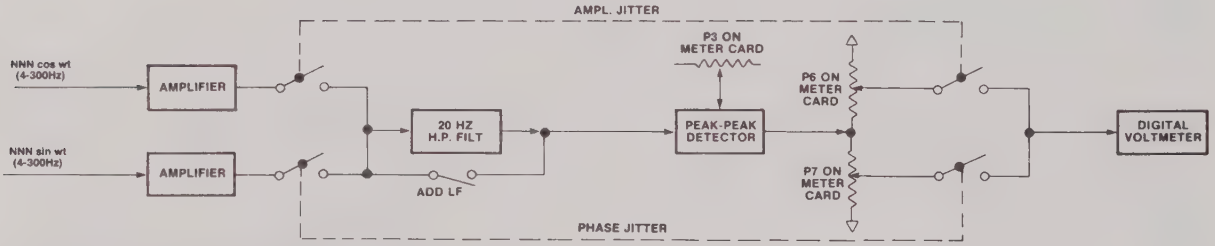
3-23. 2ND HARMONIC SEPARATION Mode (Figure 3-6E)

a. When the NN SEP, 2ND H, and HARMONIC SEPARATION buttons are depressed, the multi-mode meter measures the separation, in dB relative to tone fundamental, of the (0-3Hz) filtered second harmonic component of normalized notched noise, over the range −50 to 0dB.

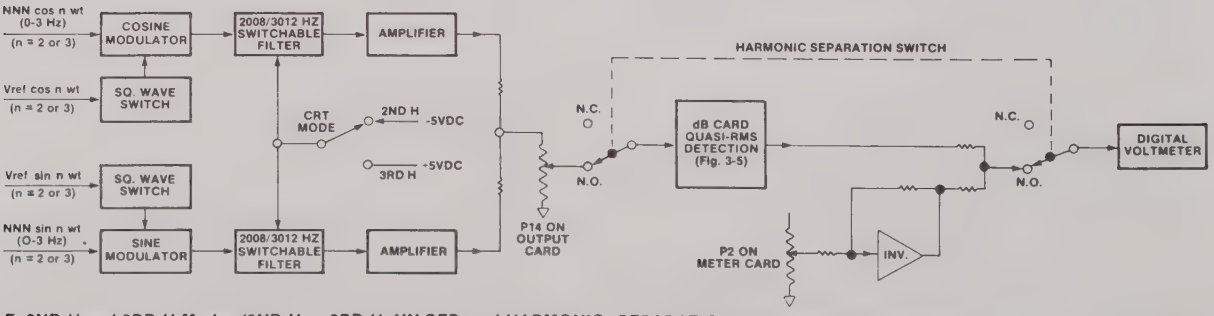








D. AMPL. JITTER and PHASE JITTER Modes



E. 2ND H and 3RD H Modes (2ND H or 3RD H, NN SEP, and HARMONIC SEPARATION buttons must be depressed)

FIGURE 3-6 MULTI-MODE METER CIRCUITS, SIMPLIFIED FUNCTIONAL DIAGRAMS

b. The (0-3Hz) filtered voltage NNNcos $2\omega t$ is fed to a cosine modulator which is keyed at 2008Hz by a square wave switch driven by the voltage $V_{ref}\cos 2\omega t$. Similarly, the (0-3Hz) filtered voltage NNNsin $2\omega t$ is fed to a sine modulator which is keyed at 2008Hz by a square wave switch driven by the voltage $V_{ref}\sin 2\omega t$.

c. The outputs of the cosine and sine modulators are fed through 2008Hz filters and amplifiers to a summing point at rms harmonic scale adjustment P14 (on the output card). The filters are 2008/3012Hz electrically switchable filters which, in the 2ND H CRT MODE, are switched to 2008Hz.

d. The output from the arm of P14 is fed through the *normally-open* contacts of the depressed HARMONIC SEPARATION switch, to the dB card. The output of the dB card is the log of the rms sum of the cosine and sine components of the second harmonic content of the normalized notched noise. The output of the dB card is summed with the output of a fixed-bias inverter and fed to the digital voltmeter. The input to the digital voltmeter ranges from +500mVdc at −50dB second harmonic separation to 0mVdc at 0dB.

3-24. 3RD HARMONIC SEPARATION Mode (Figure 3-6E)

a. When the NN SEP, 3RD H, and HARMONIC SEPARATION buttons are depressed, the multi-mode meter measures the separation, in dB relative to tone fundamental, of the (0-3Hz) filtered third harmonic component of normalized notched noise, over the range −50 to 0dB.

b. The (0-3Hz) filtered voltage NNNcos $3\omega t$ is fed to a cosine modulator which is keyed at 3012Hz by a square-wave switch driven by the voltage $V_{ref}\cos 3\omega t$. Similarly, the (0-3Hz) filtered voltage NNNsin $3\omega t$ is fed to a sine modulator which is keyed at 3012Hz by a square wave switch driven by the voltage $V_{ref}\sin 3\omega t$.

c. The outputs of the cosine and sine modulators are fed through 3012Hz filters and amplifiers to a summing point at rms harmonic scale adjustment P14 on the output card. The filters are 2008/3012Hz electrically switchable filters which, in the 3RD H CRT MODE, are switched to 3012Hz.

d. The output from the arm of P14 is fed, through the *normally-open* contacts of the depressed HARMONIC SEPARATION switch, to the dB card. The output of the dB card is the log of the rms sum of the cosine and sine components of the third harmonic content of the normalized notched noise. The output of the dB card is summed with the output of a fixed-bias inverter and fed to the digital voltmeter. The input to the digital voltmeter ranges from +500mVdc at −50dB third harmonic separation to 0mVdc at 0dB.

SECTION IV
OPERATION AND DATA INTERPRETATION

4-1. GENERAL

a. Impairment Generators. The use of the PB-1C-D for go/no-go evaluation of VF transmission facilities can be learned in a few minutes; but its use for deep diagnostics requires greater familiarity with the instrument itself and with all the different kinds and combinations of impairments it can display and measure. The time required for the operator to become familiar with the total range of capabilities of the PB-1C-D can be greatly reduced with the aid of an impairment generator which can supply selectable combinations and adjustable levels of known individual impairments. The Bradley Telcom 2A/2B Line Impairment Generator and TIG-1 Tone and Impairment Generator (described in Bulletins 1110 and 1130, respectively, which are appended to this manual) are important teaching and self-training aids for familiarizing personnel with operation of the PB-1C-D and with interpretation of its displays. The 2A/2B is also a powerful aid to the PB-1C-D in the analysis of complex unknown impairments by the method of substitution, because its output, which is a known combination of known individual impairments, can be adjusted to simulate the unknown impairments when compared with them on the PB-1C-D. Thus, when the controls on the 2A/2B are set so that the PB-1C-D display of the 2A/2B output is similar to the display of the actual impairment to be analyzed, the settings of the 2A/2B controls provide a complete analysis of the impairment. These impairment generators can be purchased from Bradley Telcom or rented from the major electronic instrument leasing companies.

b. One-Way versus Loopback Testing. One-way testing detects impairments in one direction, and loopback testing detects the sum of the impairments in both directions. Impairments observed in one-way testing of a facility but not in loopback testing of that facility are present equally and oppositely in each direction and thus cancel out. The results of loopback testing should therefore be confirmed if possible by one-way testing in at least one of the two directions, to ascertain that there are no significant one-way impairments that have been cancelled out in the loopback. Because the PB-1C-D has both an oscillator output and a signal input, it can easily be used for loopback testing of pairs of lines by patching the oscillator output to the outgoing line, patching the incoming line to the signal input, and connecting the far ends of the lines. With PB-1C-Ds at both ends, it becomes possible to perform one-way tests on either line, or on both lines at the same time, by using the outgoing and incoming lines of the near-end PB-1C-D as the incoming and outgoing lines, respectively, of the far-end PB-1C-D.

c. Remote Tone Sources. When performing one-way testing on an incoming line, it is desirable to have at the far end a precision tone source or an instrument containing such a source (e.g., a PB-1 Series VF Line Analyzer, NNE Series Transparent Line Generator, or TTL Series Touch-Tone-Addressable Loopback Transponder). Where such tone sources are not available, test tones may be obtained in the following ways:

1. A 1000Hz test tone may be dialed up or patched from supplies located in all central offices. It is well to check the harmonic level of these tone sources, at the originating office if possible.

2. A 941Hz tone may be obtained by depressing any two of the three buttons in the bottom row on Bell System L-C touch-tone pads. The 941Hz tone is within the 930 to 1030Hz tracking range of the PB-1C-D, so that it may be used for vector-notch mode measurements, but its second harmonic content may be high enough to invalidate second harmonic measurements. (If the touch-tone pad is on a telephone, it must be off hook. Room noise will not be a problem, because the microphone is disconnected when the touch-tone buttons are depressed. These statements apply also to 3 below.)

3. 941 and 1555Hz tones are provided simultaneously by depressing **#** on Bell System R-C touch-tone pads (used in Trimline phones, etc.); the 20 to 300Hz and 4 to 300Hz vector-notch modes of the PB-1C-D will reduce the 1555Hz tone by approximately 30dB.

d. Because the PB-1C-D operates in real time, two PB-1C-Ds can be used simultaneously to identify the locations of sources of transient impairments with respect to the facilities being examined. Using one PB-1C-D to examine impairments at the input of the facility and the other PB-1C-D to examine impairments at the output, it is easy to determine, *for any transient impairment*, whether the facility is initiating or merely transmitting that impairment. Since the PB-1C-D is a VF line analyzer, signals can be accessed directly at VF boards, but accessing in carrier locations will require the use of selective level meters or PCM channel demodulators. Note that the use of a Bradley Telcom NNE Series Transparent Line Generator at the far end of a transmission facility permits accessing both ends of the facility (whether those ends are in the same building or many miles apart) to two PB-1C-Ds at a single near-end location.

e. Most electrical inputs and outputs appearing at jacks on the front panel of the PB-1C-D are repeated at a 25-pin connector on the rear. The outputs may be used to drive external counters, recorders, and displays.

4-2. The PB-1C-D comprises the following test instrumentation:

a. Test Oscillator, described in Par. 2-12.

b. Fast INPUT LEVEL Meter, described in Par. 2-9c.

c. Digital Frequency Meter, described in Par. 2-10.

d. Digital Multi-Mode Meter, described in Par. 2-11.

e. Suppressed-Tone Phasor-Domain CRT, with graticule, controls, jacks and indicator as described in Par. 2-13.

The CRT can also be used as a vectorscope, by patching horizontal and vertical deflection voltages into the X, Y IN jack on the front panel.

f. Loudspeaker, as described in Par. 2-22.

4-3. OSCILLATOR OPERATION

Panel items related to the internal test-tone oscillator are a one-turn OUTPUT LEVEL control, five interlocked OSCILLATOR OUTPUT FREQUENCY pushbuttons, a ten-turn 200 TO 5000Hz variable frequency control, an OUTPUT FREQ & LEVEL pushbutton, and a 310 OUTPUT jack at which the oscillator output appears as a 600-ohm balanced voltage, dc-blocked for up to 160Vdc.

a. To use the test-tone oscillator output, patch from the 310 OUTPUT jack to the input of the circuit being tested.

b. To read the oscillator output voltage and frequency, depress the METER MODE LEVEL button and hold down the OUTPUT FREQ & LEVEL button; read the oscillator output voltage on the multi-mode meter and read the oscillator output frequency on the frequency meter.

c. To set the oscillator output voltage precisely to any desired value in its −40 to +10dBm range, depress the METER MODE LEVEL button, hold down the OUTPUT FREQ & LEVEL button, and monitor the oscillator output voltage on the multi-mode digital meter while adjusting the OUTPUT LEVEL control.

d. The oscillator output frequency is determined by the settings of the OSCILLATOR OUTPUT FREQUENCY pushbuttons and the 200 to 5000Hz control, as follows:

1. To obtain a single 1004, 2008, or 2713Hz tone, depress the button labeled 1000, 2000, or 2713.

2. To obtain a 1004Hz tone with a 2008Hz tone 10dB down from the 1004Hz tone, depress the 1000+2000Hz button. This output is for use with Bradley Telcom Transparent Line Generators, but it is useful whenever a tone with a large second harmonic is desired to check facilities for frequency translation or other forms of time-varying phase-intercept distortion.

3. To obtain any output frequency in the range 200 to 5000Hz, depress the VAR button and adjust the 200 TO 5000Hz control. **To set the variable output frequency** precisely to any desired value in its 200 to 5000Hz range, depress the VAR button, hold down the OUTPUT FREQ & LEVEL button, and monitor the oscillator output frequency on the digital frequency meter while adjusting the 200 TO 5000Hz control.

4-4. FREQUENCY METER OPERATION

The four-digit frequency meter measures and displays the frequencies of selected voiceband signals, if the levels of those signals are between −35 and +10dBm. Panel items related to the frequency meter are the 310 INPUT jack, NN FREQ button, and OUTPUT FREQ & LEVEL button.

a. To read the frequency of a tone at the INPUT jack, do not depress either the NN FREQ or the OUTPUT FREQ & LEVEL buttons.

b. To read the output frequency of the internal test-tone oscillator, hold down OUTPUT FREQ & LEVEL.

4-5. MULTI-MODE METER OPERATION

The multi-mode meter displays the values of parameters selected by five interlocked METER MODE pushbuttons (labeled LEVEL, NOISE, NN SEP, AMPL. JITTER, and PHASE JITTER) and four momentary pushbuttons (labeled REMOVE FILTER, ADD LF, OUTPUT FREQ & LEVEL AND HARMONIC SEPARATION).

a. To read the average-detected level of the INPUT signal, depress the LEVEL button. The input signal level range is −45 to +9.9Bm, as measured through a 200Hz high-pass filter and a high-frequency noise-blocking low-pass filter. To make more accurate level measurements at frequencies below 200Hz, also hold down the REMOVE FILTER button to disconnect the 200Hz high-pass filter. Note the following:

1. Input levels greater than +9.9Bm will cause all digits to be blanked and dashes to be displayed before and after the decimal point.

2. The level of the input signal can always be read on the fast INPUT LEVEL meter regardless of the settings of the METER MODE buttons, because the INPUT LEVEL meter is connected directly across the INPUT jack and is thus independent of the multi-mode meter switches.

3. If the input signal contains neither tone nor data, the meter will indicate the average-detected background noise level of the channel in dBm.

b. To measure the dBrnC level of the INPUT signal, quasi-rms-detected and C-Message weighted, depress the NOISE button. The range is 20 to 80 dBrnC (−70 to −10dBm). To measure the quasi-rms-detected level of the INPUT signal in dBrn (i.e., without C-Message weighting, or 'flat'), also hold down the REMOVE FILTER button. Note the following:

1. If the INPUT signal is a test tone or a data signal, the meter will indicate the level of that signal.

2. Only if the input signal comes from a resistively terminated line (i.e., one with neither tone nor data), will the meter indicate the background noise level of that line.

c. To measure the notched noise separation or level in dB relative to the level of the input tone, with C-Message and wide band weighting, depress the NN SEP button. The range is 50 to 0dB. To measure the notched noise separation without C-Message weighting, also hold down the REMOVE FILTER button. To measure notch noise separation C-message, narrow notch weighted, hold down the NN SEP PUSH FOR NARROW NOTCH button only. To measure flat weighted narrow notch separation hold down both the REMOVE FILTER and the NN SEP PUSH FOR NARROW NOTCH buttons. Note the following:

1. The multi-mode meter will display notched noise separation:

a) if NN SEP is depressed, regardless of the settings of the CRT MODE buttons;

b) if the HARMONIC SEPARATION button is not depressed.

2. The NN SEP measurement is valid only if the DO NOT READ indicator is off (See Par. 2-13a).

3. The displayed value of NN SEP is 14dB less than the input value when the NNE switch is set to ATTEN and the SCALE CHANGE ON RED FUNCTIONS indicator is flashing.

d. To measure the percent amplitude jitter in the INPUT signal over the 20 to 300Hz band, depress the AMPL JITTER button and any CRT MODE/VECTOR NOTCH button. The range is 0 to 50%. To measure amplitude jitter over the 4 to 300Hz band, also hold down the ADD LF button. Note the following:

1. The multi-mode meter will display amplitude jitter only if the AMPL JITTER button and any VECTOR NOTCH/CRT MODE button are depressed. The bandwidth of the amplitude jitter measurement is 20 to 300Hz (or 4 to 300Hz if the ADD LF button is also held down), regardless of which VECTOR NOTCH button is depressed.

2. The amplitude jitter measurement is valid only if the DO NOT READ CRT & RED FUNCTIONS indicator is off (see Par. 2-13a).

3. The multi-mode meter will be blanked if the AMPL JITTER button and either the 2ND H or the 3RD H CRT MODE button are depressed.

4. The displayed value of amplitude jitter is the input value divided by 5 when the NNE switch is set to ATTEN and the SCALE CHANGE ON RED FUNCTIONS indicator is flashing. (see Par. 2-23).

e. To read degrees of phase jitter in the INPUT signal in the 20 to 300Hz band, depress the PHASE JITTER button and any VECTOR NOTCH CRT MODE button. The range is 0 to 50°. To measure phase jitter in the 4 to 300Hz band, also hold down the ADD LF button. Note the following:

1. The multi-mode meter will display phase jitter only if the PHASE JITTER button and any VECTOR NOTCH CRT MODE button are depressed.

2. The phase jitter measurement is valid only if the DO NOT READ CRT & RED FUNCTIONS indicator is off (see Par. 2-13a).

3. The multi-mode meter will be blanked if the PHASE JITTER button and either the 2ND H or 3RD H CRT MODE button are depressed.

4. The displayed value of phase jitter is the input value divided by 5 when the NNE switch is set to ATTEN and the SCALE CHANGE ON RED FUNCTIONS indicator is flashing. (see Par. 2-23).

f. To read the level of the second harmonic in dB relative to the input tone, depress the 2ND H, HARMONIC SEPARATION and the LEVEL, NOISE, or NN SEP buttons. Note the following:

1. The multi-mode meter will display second harmonic separation only if the 2ND H, HARMONIC SEPARATION, and the LEVEL, NOISE, or NN SEP buttons are depressed.

2. The second harmonic separation measurement is valid only if the DO NOT READ indicator is off (see Par. 2-13a).

3. The multi-mode meter will be blanked if the HARMONIC SEPARATION button and any VECTOR NOTCH button are both depressed.

4. The multi-mode meter will be blanked if the 2ND H button and either the PHASE JITTER or AMPL JITTER buttons are depressed.

g. To read the level of the third harmonic in dB relative to the input tone, depress the 3RD H and HARMONIC SEPARATION buttons, and either the LEVEL or the NN SEP button. Note the following:

1. The multi-mode meter will display third harmonic separation only if the 3RD H, HARMONIC SEPARATION, and either the LEVEL or the NN SEP buttons are depressed.

2. The third harmonic separation measurement is valid only if the DO NOT READ CRT & RED FUNCTIONS indicator is off (see Par. 2-13a).

3. The multi-mode meter will be blanked if the 3RD H button and either the PHASE JITTER or AMPL JITTER buttons are depressed.

4. The multi-mode meter will be blanked if the HARMONIC SEPARATION button and any VECTOR NOTCH button are both depressed.

4-6. USE OF THE FAST INPUT LEVEL METER

This meter has no panel controls. It comprises a linear horizontal array of 18 vertical LED bars, each bar being centered under a vertical graduation printed on the panel. The graduations represent 3dBm steps from −42dBm to +9dBm as follows: **−42**, −39, **−36**, −33, **−30**, −27, **−24**, −21, **−18**, −15, **−12**, −9, **−6**, −3, **−0**, −3, **+6**, and +9, of which the boldface numbers are printed on the panel above the corresponding graduations. The fast input level meter circuit measures the positive peak of the input voltage and lights the corresponding LED. Only one LED is actually lit at any instant, although two or more adjacent LEDs may appear lit in response to rapid variations of input voltage levels.

4-7. SPEAKER OPERATION

The acoustic output of the panel-mounted loudspeaker is controlled by the SPEAKER MODE switch and the SPEAKER VOLUME control. The gain of the speaker amplifier is such

that low-level inputs will be clearly audible; however, input levels above −20dBm will saturate the amplifier if the SPEAKER VOLUME control is set too high. Saturation will be immediately obvious because audible harmonics will be present which disappear at lower SPEAKER VOLUME settings.

a. To hear the entire input signal (tone plus notched noise), set the SPEAKER MODE switch to INPUT, and adjust the SPEAKER VOLUME control for desired sound level.

b. To hear the notched noise in the input signal, set the SPEAKER MODE switch to NOTCH, and adjust the SPEAKER VOLUME control for the desired sound level. Note the following:

1. Since the notched noise is generally much lower than the tone, additional amplification is automatically inserted in the SPEAKER NOTCH MODE.

2. The acoustic output in the NOTCH position of the SPEAKER MODE switch is the notched noise only if the DO NOT READ indicator is off, which occurs only when the input tone is within the ranges 930 to 1030Hz and −40 to +10dBm, and the tracking circuits are locked to the input signal. If the DO NOT READ light is on, the acoustic output of the speaker in the NOTCH mode is the local oscillator only, and may be painfully loud.

3. The notched noise output is very useful, because it permits listening to the impairments in the input signal without the masking effect of the much larger tone component of the input signal. Each type of impairment has its own characteristic acoustic 'signature' by means of which it can be recognized. The notched-noise acoustic output is thus an extremely valuable aid in the identification of impairments. Descriptions of the notched-noise acoustic outputs corresponding to the different types of impairments are given in Figures 12 through 29 of Bulletin 2010.

4. The SPEAKER NOTCH MODE is fed through the 200Hz high pass filter. To hear the low frequency components (i.e., 60Hz), hold down the REMOVE FILTER BUTTON while listening.

c. To turn off the speaker, set the SPEAKER MODE switch to its center-off position.

4-8. PHASOR-DOMAIN CRT OPERATION

4-9. Vector Notch Measurements

a. Patch the received signal to the INPUT jack, and set the 600Ω/BRIDGE and HOLD COIL switches for the desired input conditions. Observe that the DO NOT READ CRT & RED FUNCTIONS indicator is off; this means that the PB-1C-D tracking circuits are locked to the input signal.

b. Depress one of the following CRT MODE buttons: 4 TO 20, 20 TO 300, 4 TO 300, or UNFILT. The in-phase component (NNN cos ωt) of normalized notched noise is displayed as a vertical deflection, and the quadrature component (NNN sin ωt) is displayed as a horizontal deflection. The sensitivities of these deflections are controlled by the settings of the SCALE MULT pushbuttons.

c. In-phase or amplitude disturbances deflect the CRT spot vertically; an increase in amplitude deflects the spot upward, and a decrease in amplitude deflects the spot downward. Vertical deflections can be read against the CRT graticule vertical scale, which is calibrated in percent from −6% at the bottom, through −4%, −2%, −0%, +2%, +4%, to +6% at the top. Note that the vertical deflection must be multiplied by the SCALE MULT HOR/VERT factor to obtain the amplitude jitter in percent.

d. Phase or quadrature disturbances deflect the CRT spot horizontally; phase lead deflects the spot to the right, and phase lag deflects the spot to the left. Horizontal deflections can be read against the graticule horizontal scale, which is calibrated in degrees of arc from −3° at the left, through −2°, −1°, (0°), +1°, +2°, to +3° at the right. Note that the horizontal deflection must be multiplied by the SCALE MULT HOR/VERT factor to obtain the phase jitter in degrees. Phase jitter is defined as a peak-to-peak value and is therefore equal to the total horizontal excursion. For example, if the deflection extends from −2° to +2°, the phase jitter reading is 4°.

e. Although the vertical scale is calibrated in percent and the horizontal scale is calibrated in degrees of arc, the multiplier factors (X0.5, X1, X2, X5 and X10) selected by the SCALE MULT buttons apply to both vertical and horizontal scales. When the SCALE MULT X1 button is depressed, both vertical and horizontal deflections may be read directly. For other settings of the SCALE MULT buttons, multiply the graticule vertical and horizontal readings by the scale multiplier factor indicated by the SCALE MULT setting. Note that the deflection sensitivity is reduced by a factor of 5, i.e., × 1/5, when the NNE switch is set to ATTEN.

f. Deflections in any direction may also be measured against polar scale circles that are calibrated in dB from −30dB (the unnumbered smallest circle) through −20dB, −16dB, −14dB, −12dB, to −10dB (the largest circle). Deflections read against the polar scale circles must be added algebraically to the dB level (−20, −14, −8, 0, or +6dB) indicated by the SCALE MULT buttons. Thus, if the −8dB SCALE MULT button is depressed, an impairment that causes a radial deflection to the −14dB circle has a level of (−8) + (−14) = −22dB with respect to the quiet tone. If the −20dB SCALE MULT button is depressed, an impairment that causes a radial deflection to the −30dB circle has a level of (−20) +(−30) = 50dB with respect to the quiet tone. Note that deflection sensitivity is reduced by 14dB when the NNE switch is set to ATTEN.

g. The horizontal deflection only or the vertical deflection only of the CRT display may be examined by holding the SINGLE AXIS switch at HOR or VERT, respectively.

4-10. Distortion Measurements In UNFILT VECTOR NOTCH CRT MODE

a. Second and third harmonic distortion can be measured in the UNFILT VECTOR NOTCH mode, as well as in the 2ND H and 3RD H modes described in Par. 4-11 below. Because harmonics of the test tone are coherent with that test tone, in the UNFILT VECTOR NOTCH mode they form cloverleaf patterns that indicate the order of the harmonic. Pure second harmonic forms a four-lobe cloverleaf pattern and pure third harmonic forms a six-lobe cloverleaf

pattern that is folded over into two nearly-coincident three-lobe cloverleaf patterns. These patterns may rotate continuously in the presence of frequency translation (if the distortion occurs *before* the frequency translation, but not if the distortion occurs *after* the frequency translation), rotate through limited angles in the presence of low-frequency jitter, or expand and contract in the presence of harmonic hits or of harmonics from multiple sources separated by a transmission facility in which frequency translation occurs.

b. In the UNFILT VECTOR NOTCH mode, distortion levels in dB below quiet tone level are measured on the polar scales in the same way that random-direction radial deflections are measured, as described in Par. 4-9f. Measurements of reasonable accuracy are not feasible unless a single harmonic predominates, which is not usually the case.

4-11. Distortion Measurements In 2ND H and 3RD H Modes

a. The 2ND H and 3RD H buttons select the second and third harmonic distortion components of the received tone for display and measurement. The deflection amplitude is a measure of the distortion magnitude, and the deflection angle is a measure of the phase-intercept distortion of the channel. Since phase-intercept distortion is an uncontrolled parameter, the deflection may be in any direction. It is therefore usually convenient to read the deflection against the circular dB scales. Note again that the dB markings of the SCALE MULT buttons indicate the number of dB to be added to or subtracted from the circle calibrations. In the most sensitive SCALE MULT setting (−20dB), the inner circle (−30dB) corresponds to a separation of −50dB; i.e., the harmonic level is 50dB below tone level.

b. The measurement is limited by the filter bandwidth, which is made narrow to keep the erratic spot motion induced by background noise below acceptable limits relative to the lowest harmonic distortion measurement threshold (50dB below signal level). Where it is desired to study the phase-intercept distortion, a harmonically-rich 1004Hz + 2008Hz signal can be transmitted by depressing the 1000+2000Hz OSCILLATOR OUTPUT FREQUENCY button. The 2008Hz 'harmonic' will be 10dB below the 1004Hz 'fundamental'.

4-12. MEASUREMENT TECHNIQUES

a. The PB-1C-D can be used to identify and measure each of the impairments defined in Par. 1-20, even when they occur in complex combinations. The discussion in the following paragraphs covers correlated use of the CRT, panel meters, and loudspeaker in identifying and measuring the different kinds of impairments. Such correlated use increases the analytical capabilities of the instrument.

b. Note that the setting of the SCALE MULT button must be taken into account when measuring impairments on the CRT. Note also that all CRT measurements, and all digital meter measurements that are controlled by red buttons, are valid only when the DO NOT READ CRT & RED FUNCTIONS indicator is dark.

4-13. Notched Noise Measurements

a. CRT measurements of the notched noise in the input signal can be made in any VECTOR NOTCH CRT MODE. The UNFILT mode provides the greatest amount of information, but depressing the 4 TO 20Hz, 20 TO 300Hz, or 4 TO 300Hz buttons permits measuring the notched noise in those frequency bands. The maximum radial excursion is equal to the peak value of the notched noise. The peak value is more indicative of impairments that cause data errors than is rms noise, because high-speed modems respond virtually instantaneously to impairments.

b. Multi-Mode Meter readings of the notched noise level (quasi-rms detected, C-Message weighted, in dB below input tone) can be made when the NN SEP button is depressed. Hold down the REMOVE FILTER button to remove the C-Message weighting, and the meter reading will generally increase because of the added components (predominantly power-frequency pickup), which were not passed by the C-Message filter. A rule of thumb for a 'good' line (i.e., one without too much 60Hz) is that the meter reading should not increase by more than 10dB when the REMOVE FILTER button is held down. Note that this rule of thumb is **not** a tariff requirement.

c. Speaker output is normalized notched noise when SPEAKER MODE switch is set to NOTCH.

4-14. Impulse Noise Measurements

a. CRT measurements of impulse noise hits in the input signal can be made in the UNFILT VECTOR NOTCH mode. Impulse noise hits appear as radial excursions in the random directions. The peak excursion is the impulse noise separation in dB relative to the tone. Note that this gives the same impulse noise separation as schemes which measure absolute magnitudes of impulse noise and tone in dBm, and which thus require subtracting the dBm of impulse noise from the dBm of tone to obtain impulse noise separation in dB relative to tone.

b. Multi-Mode Meter is too slow to measure impulses.

c. Speaker NOTCH MODE output will be clicking or popping sounds simultaneous with the CRT excursions.

4-15. Single-Frequency Interference (SFI) Measurements

a. CRT displays of pure SFI and of SFI plus steady noise will resemble those shown in Figures 15 and 16 of Bulletin 2010. The experienced operator can diagnose SFI from the CRT display.

b. Multi-Mode Meter cannot measure SFI separately, but only as part of notched noise.

c. Speaker NOTCH MODE output is a single tone.

4-16. Phase-Jitter Measurements

Note: Phase jitter includes the combined effects of phase modulation and noise so that, if phase modulation is low and noise level is high, phase jitter measurements will be affected almost entirely by the noise level.

a. CRT displays of phase jitter show horizontal excursions in all VECTOR NOTCH modes. The UNFILT mode shows all

phase jitter components; the 4 TO 20Hz, 20 TO 300Hz and 4 TO 300Hz modes show phase jitter components in those bands only.

1. For each VECTOR NOTCH mode, use the SCALE MULT setting that gives the most readable display.

2. Hold the SINGLE-AXIS switch at HOR, note the excursions to the left and to the right as measured on the horizontal scale, and add the absolute values of the two measurements to obtain the total horizontal excursion.

3. Multiply the total horizontal excursion by the SCALE MULT factor to obtain the phase jitter in degrees.

4. Example: at a X5 SCALE MULT setting, the left excursion is -1.4 and the right excursion is $+1.4$. The phase jitter is therefore $(1.4+1.4)X5 = (2.8)X5 = 14°$.

b. Multi-Mode Meter displays phase jitter when PHASE JITTER button is depressed. Hold down ADD LF button to measure contribution of low-frequency phase jitter.

c. Speaker: the sidebands of pure phase modulation and the hissing sound of noise will both be audible.

4-17. Phase-Hit Measurements

a. CRT displays phase hits as rapid single horizontal excursions in all VECTOR NOTCH modes. The UNFILT mode shows all voice-frequency components of phase hits; the 4 TO 20Hz, 20 TO 300Hz and 4 TO 300Hz modes can be used to measure phase-hit components in those bands.

1. Depress UNFILT mode button.

2. Use a SCALE MULT setting that gives adequate horizontal deflection.

3. Hold SINGLE AXIS switch at HOR and measure on the horizontal scale the maximum excursion, whether to the left or to the right.

4. Multiply maximum excursion by SCALE MULT setting to obtain peak phase hit in degrees.

5. Example: maximum excursion is 2, at X10 SCALE MULT setting. The phase hit magnitude is therefore $2X10 = 20°$. Note that, unlike phase jitter (which is measured peak-to-peak), phase hits are measured zero-to-peak.

b. Multi-Mode Meter cannot detect phase hits.

c. Speaker NOTCH MODE output is a pinging sound, which occurs at same time as CRT excursion.

4-18. Gain Hit/Dropout Measurements

a. CRT displays changes in signal amplitude as vertical excursions in all VECTOR NOTCH modes; gain hits and dropouts appear as rapid vertical excursions. The UNFILT mode shows all components of gain hits and dropouts; the 4 TO 20Hz, 20 TO 300Hz and 4 TO 300Hz modes will measure gain-hit/dropout components in those bands.

1. Depress UNFILT button.

2. Select a SCALE MULT setting that gives most readable vertical deflection.

3. Hold SINGLE AXIS switch at VERT and measure on the vertical scale the maximum excursion, whether up or down.

4. Multiply the maximum excursion by the SCALE MULT factor.

b. Multi-Mode Meter cannot detect either gain hits or dropouts.

c. Speaker NOTCH MODE output is a pinging sound which occurs at same time as CRT excursion.

4-19. Harmonic Measurements

a. CRT displays second harmonic (in 2ND H mode) or third harmonic (in 3RD H mode). Note: high noise levels will affect harmonic readings by causing erratic spot motion. This can be averaged visually.

1. Depress 1000Hz OSCILLATOR OUTPUT FREQUENCY button, patch oscillator OUTPUT jack to input of facility being tested, and patch output of facility into PB-1C-D INPUT jack.

2. Depress 2ND H button and select SCALE MULT factor giving most readable radial deflection on the dB scale. Measure the radial deflection in dB and add this to the SCALE MULT dB value. Example: CRT radial deflection is -14dB and SCALE MULT setting is -20dB. The sum $(-14) + (-20) = -34$dB second harmonic. In other words, the second harmonic level is 34dB lower than the tone level, or the second harmonic separation is 34dB.

3. Depress 3RD H button and select SCALE MULT setting giving most readable display. Measure the radial deflection in dB and add this to the SCALE MULT setting to obtain the third harmonic separation.

b. Multi-Mode Meter displays second harmonic separation when 2ND H, HARMONIC SEPARATION, and either the LEVEL or NN SEP buttons are depressed, and displays third harmonic separation when 3RD H, HARMONIC SEPARATION, and either the LEVEL or NN SEP buttons are depressed.

4-20. Frequency Shift (Translation)

a. Because frequency shifts in outgoing and return lines can cancel when making loopback measurements, it is necessary to have a harmonically-rich remote source of 1004Hz tone. This remote source may be a Bradley Telcom TLG, a second PB-1C-D, or other distortion source in the facility ahead of the frequency translation.

b. The local **CRT** can identify and measure frequency translation, as follows:

1. Depress local 2ND H button.

2. Depress 1000+2000Hz button on remote PB-1C-D, and patch remote oscillator OUTPUT jack to input of facility being tested.

3. Patch output of facility being tested into local PB-1C-D INPUT jack.

4. If a rotation of the display appears, the rate of rotation is equal to the frequency shift or translation caused by the facility under test; e.g., if the display rotates at a rate of 3 revolutions per second, the frequency shift is 3Hz. Direction of rotation indicates direction of shift; ccw is upward shift, cw is downward shift.

c. Multi-Mode Meter does not measure frequency.

4-21. INTERPRETATION OF PB-1C-D CRT DISPLAYS

4-22. General

a. The illustrations on pages 8 through 11 of Bulletin 2010 represent a catalog of PB-1C-D displays corresponding to various conditions. Those illustrations are useful aids for analysis of impairments by comparison with PB-1C-D displays. Under each illustration is a description of the conditions causing the display, as well as a description of the corresponding sound output, which is a valuable auxiliary aid in diagnosis.

b. The Bradley Telcom Model 2A/2B Line Simulator can be used to cause PB-1C-D displays similar to those caused by the facility under test. The impairments in that facility can then be determined from the 2A/2B control settings that cause the similar display. This substitution technique is especially useful for analyzing 'new' impairments, i.e., those that have not been cataloged previously.

c. With practice, the PB-1C-D operator can learn to analyze even complex displays directly, without recourse to the aids in a. and b. above.

4-23. Analysis Of Impairments In Vector Notch Mode

a. Figures 12 through 25 of Bulletin 2010 represent PB-1C-D displays in the 20 TO 300Hz and UNFILT VECTOR NOTCH positions. The left hand photograph of each figure was taken at 20 TO 300Hz, and the right-hand photograph of each figure was taken at UNFILT. The 20 TO 300Hz VECTOR NOTCH filter provides displays compatible with conventional Bell System and CCITT Phase Jitter test sets and with the Bradley Telcom Model 75LPA Phase and Amplitude Jitter Set. The Bell System and CCITT Phase Jitter test set filters limit the impairment bandwidths displayed to those in the sidebands 20 to 300Hz below the test tone and 20 to 300Hz above the test tone. In contrast, the UNFILT VECTOR NOTCH mode of the PB-1C-D provides displays of the entire spectrum of impairments from 4 to 3500Hz, with a notch bandwidth so narrow that all impairment frequencies except those within ±1Hz of the test tone frequency may be observed.

b. In general, phase modulation causes essentially horizontal deflections, amplitude modulation causes vertical deflections, noise causes deflections at random angles, and SFI causes circular motions. If the VECTOR NOTCH pattern is much wider than it is high, phase jitter is predominant. If the pattern is higher than it is wide, amplitude jitter is predominant. We have not had any reports of observed amplitude modulation on any carrier facilities; however, seven-segment PCM systems have quantizing approximation error patterns which are higher than they are wide. Also, the rather large-angle, low-frequency jitter occasionally present (because of improper phase-lock-loop operation) in FDM systems which recover reference tones from the received signal, produce a second AM-like pair of sidebands which are detected as amplitude jitter. If the display is equally large in all directions, the problem is noise or SFI. In all cases, background noise may be regarded as adding to the modulation impairment; thus, phase modulation plus noise produces a pattern in which the amount of phase modulation can be estimated by subtracting the vertical deflection from the horizontal deflection.

c. An idea of the predominant jitter frequency can be obtained by depressing the various VECTOR NOTCH buttons. Sideband frequencies in the 4 TO 20Hz, 20 TO 300Hz, 4 TO 300Hz and UNFILT ranges will appear when the corresponding buttons are depressed. If there is a predominant single frequency in the modulation pattern, this can be heard on the speaker as two sidebands. For low-frequency jitter, use the UNFILT and 4 TO 20Hz VECTOR NOTCH modes.

d. If a predominant SFI pattern can be seen in the UNFILT mode but cannot be heard, it is likely to be power-line related components of frequencies at which the small speaker in the PB-1C-D does not have much response.

e. In the detection of modulation impairments by the PB-1C-D, the notched noise is translated downward in frequency by the amount of the test tone and is thus centered at dc with the lower sideband folded back onto the upper sideband. This is accomplished by an internal modulator which multiplies the notched noise by the reference tone. At the same time, the same modulator translates the notched noise up to twice the tone frequency,because the modulator produces the sum as well as the difference frequencies of its two inputs. In the 4 TO 20Hz, 20 TO 300Hz, and 4 TO 300Hz modes, the double-tone-frequency components are filtered out, so that only the dc-centered sidebands are displayed. In the UNFILT mode, both the dc-centered and double-tone-frequency sidebands are displayed. Modulation impairments thus show up two ways in the UNFILT mode. This is really a reflection of the instrumentation used to reduce them to a display and is not a picture of what is actually happening to the tip of the tone vector. It is useful because it allows modulation impairments, to be observed even in the presence of a larger amount of noise.

f. In the UNFILT VECTOR NOTCH mode, phase modulation appears as two circles that are tangent to the vertical axis at the origin, and amplitude modulation appears as two circles that are tangent to the horizontal axis at the origin. Transient phase phenomena appear as a circle which expands and contracts to the right or left of the vertical axis at the origin, and transient amplitude phenomena appear as a circle which expands and contracts above or below the horizontal axis at the origin. Low-frequency modulation appears as circles that alternate from one side to the other of the tangent axis, growing and shrinking as they alternate. This process occurs at the jitter frequency. The oscillation frequency may be determined by counting the cycles which occur in a timed interval. The jitter amplitude may be measured by noticing the peak amplitude of the oscillatory motion. The oscillating figure is more or less distinctly delineated, depending on the rela-

tive magnitude of the low frequency jitter with respect to the remaining impairments, but the magnitude of oscillation can always be accurately estimated because the pattern motion is distinct, i.e., the edge of the pattern moves an amount equal to the jitter magnitude. The measurement of jitter frequency is important because all low-frequency jitter meters (including the Bradley Telcom Model 75LPA, as well as the PB-1, PB-1C and PB-1C-D), start to roll off at 4Hz. The roll off specified in IEEE P743/D2 can be used to correct the reading. Many cases of low-frequency jitter observed with the PB-1C-D display a jitter frequency of between 1 and 2Hz and a corrected jitter magnitude in excess of 25 degrees.

g. Gain hits are tone-correlated impairments which cause vertical deflections and pinging or (if short enough) popping sounds. Phase hits are tone-correlated impairments which cause horizontal deflections and pinging or (if short enough) popping sounds. Simultaneous gain and phase hits (called 'coincidence hits') cause deflections at angles between the vertical and horizontal, and pinging or (if short enough) popping sounds. Repeated coincidence hits will generally cause repeated deflections at approximately constant angles. Impulse hits (also called impulses and impulse noise) are non-tone-correlated impairments which cause deflections in random directions, and popping sounds.

h. FDM channels (e.g., L and N carriers) tend to have tone-correlated phase impairments. FDM systems in which the demodulation reference is transmitted with the signals have failure modes in which low-frequency phase jitter predominates. FDM systems with an independent sync chain have predominant jitter in the 20 to 300Hz passband. These latter systems may display some varying phase-intercept distortion (slow phase hits) or continuous small phase hits. These latter hits are usually brief in duration.

i. PCM systems (e.g., T-carriers) are characterized by noise-like patterns, which are actually complex Lissajous figures in which (for seven-segment systems) the in-phase impairment usually exceeds the quadrature impairment. T-carrier noise patterns may have peculiar systematic shapes which vary quite noticeably with tone frequency as it affects the sampling frequency foldback products. The shapes differ between manufacturers, reflecting the different design choices made by each. The acoustic output has an easily-identifiable characteristic sound like that of gears grinding.

4-24. Distortion Analysis in the UNFILTERED VECTOR NOTCH CRT MODE (See Figures 26 - 29 of Bulletin 2010)

a. Figures 26 through 29 of Bulletin 2010 show second and third harmonic distortion in the UNFILT VECTOR NOTCH mode. Such distortion is visible in the UNFILT mode, but is out of the passbands of the 4 TO 20Hz, 20 TO 300Hz, and 4 TO 300Hz filters.

b. Because harmonics of the test tone are coherent with that test tone, they form cloverleaf patterns that indicate the order of the harmonic. Pure second harmonic forms a four-lobe cloverleaf pattern; pure third harmonic forms a six-lobe clover-leaf pattern that is folded to make two nearly-coincident three-lobe cloverleaf patterns. Continuously rotating patterns indicate that frequency translation is occurring after the distortion. Rotation of the pattern through limited angles indicates low-frequency jitter. Expanding and contracting patterns without rotation indicate harmonic hits.

4-25. Harmonic Distortion Analysis in the 2ND H and 3RD H CRT MODES (See Figures 30 and 31 of Bulletin 2010)

a. The 2ND H and 3RD H CRT MODE buttons select the second and third harmonic distortion components of the received tone for display and measurement. Figure 31 in Bulletin 2010 is a typical 2ND H or 3RD H display. The deflection amplitude is a measure of the distortion magnitude, and the deflection angle is a measure of the phase-intercept distortion of the channel. Since phase-intercept distortion is an uncontrolled parameter, the deflection may be in any direction at random.

b. When frequency translation is present, the phase-intercept distortion angle changes continuously at a constant rate and the spot moves in a circular path, as shown in Figure 31B of Bulletin 2010. The impairment location causing it is shown in Figure 30. Note that at the receive terminal, the frequency of distortion content, $k_T \cos(2\omega t + st)$ differs from twice the frequency of the fundamental, $\cos 2(\omega t + st)$, by the amount st. This is the equivalent of an SFI input at a beat frequency st.

c. When second harmonic distortion, $k_R \cos(2\omega t + 2st)$, is introduced at the receive terminal *after* the frequency translation, it is distortion of the received frequency; it is thus exactly double the received frequency and produces a stationary spot. In Figure 31C, note that the circle radius (k_T) corresponds to the distortion which occurs ahead of the frequency translation; the offset (k_R) of the center of the circle corresponds to the distortion which has occurred after the frequency translation; and the rate at which the circle is traversed by the spot is a measure of the frequency of translation. The foregoing analysis may be extended to third harmonic distortion.

d. There may be multiple frequency translation sources as well as other phenomena which cause variations in the phase-intercept distortion angle. Phase hits cause intermittent angular motion of the spot. Phase modulation causes oscillatory angular motion of the spot. Filters limit the display bandwidth in the harmonic modes so that only low-frequency jitter can be thus observed. There may also be harmonic amplitude hits, usually involving PCM carrier, which cause radial motion of the spot. Large irregular or jagged circles encountered in PCM systems are an indication that the compandor or the aliasing filters are not functioning properly. Depending upon its magnitude, this phenomenon may render a facility incapable of passing data. This particular problem is not observable with conventional test equipment because the filtering involved in reducing the phenomenon to a meter reading severely attenuates the impairments. There are normally multiple distortion sources, although in a trouble situation one will usually predominate. These phenomena may occur at any voice appearance in the transmission path, with unpredictable phase-intercept distortion between their point of generation and the final output. The result is spot motion in random directions. The operational significance of the above is that if the distortion spot displays high mobility it is an indication that the channel will have trouble passing data.

4-26. Phase-Intercept Distortion. (See Figures 32 and 33 of Bulletin 2010)

a. The time delay suffered by any frequency component passing through a transmission medium is the slope of the line joining that point on the curve with the origin on a phase vs. frequency plot. One condition required for undistorted transmission of a complex wave shape is that the phase vs. frequency curve (plotted in linear units, and extrapolated down to dc) be a straight line passing through the origin. This is the response corresponding to a pure time delay. The slope of this line is the time delay, t. Dimensionally, $\phi/\omega = t$; radians/(rad/sec) = sec. Intuitively there is no time-domain waveshape distortion because all frequency components have the same time delay and therefore arrive in the same relative phase at the far end as they leave at the launching end.

b. Note that a perfectly linear phase vs. frequency curve (zero envelope-delay distortion) is not a sufficient condition for low baseband distortion because, referring to Figure 32 of Bulletin 2010, the time delay ϕ_1/ω_1 of frequency component ω_1 is entirely different from the time delay ϕ_2/ω_2 of frequency component ω_2. This distortion is a result of the angle at the extrapolated intersection of the phase vs. frequency curve with zero frequency. This is known as the phase-intercept distortion. It is an uncontrolled parameter in most communications systems, and it is the reason for the existence of modems, which compensate for phase-intercept distortion.

c. The angular displacement of the spot for either second or third harmonic distortion measurement is a measure of the phase-intercept distortion. In the mechanization of the PB-1C-D the received tone, cos ($\omega t + \phi_\omega$) is tracked. It is then doubled, i.e., cos ($2\omega t + 2\phi_\omega$). The phase and amplitude of the second harmonic cos($2\omega t + \phi 2_\omega$) is plotted with respect to the double-frequency tone as a reference. Referring to Figure 33 of Bulletin 2010, which is a phase vs. frequency plot, the phase difference between cos ($2\omega t + 2\phi_\omega$) and cos ($2\omega t + \phi 2_\omega$) is ($2\phi_\omega - \phi 2_\omega$). This is the deflection angle of the harmonic distortion spot. It is also the phase-intercept distortion based on measurement at frequencies ω and 2ω. A similar observation is true with respect to the third harmonic.

d. Angular motion of the harmonic 'spot' corresponds to changes in phase-intercept distortion. This motion will always be along an arc of some circle for a given distortion source and the phase-intercept distortion due to that source. However, several harmonic distortion sources may exist in a transmission channel relative to several phase-intercept distortion sources. The case of frequency translation described above is commonly encountered.

e. The measurement is limited by the filter bandwidth. This must be narrow to keep the erratic spot motion induced by background noise within acceptable limits relative to the lowest harmonic distortion measurement threshold (50dB below signal level). Where it is desired to study the phase-intercept distortion, a harmonically rich signal can be transmitted by depressing the OSCILLATOR OUTPUT FREQUENCY 1000+2000Hz button. This raises the harmonic level above the noise level. The presence of a highly mobile harmonic spot when an FDM system is probed in this way is an indication that the primary frequency supply is in trouble. This phenomenon, which can only be observed in the phasor domain, is data-inimical. It renders modems (as opposed to limited-distance modems or line drivers) incapable of compensating for the phase-intercept distortion angle which is the only reason for their existence.

4-27. PB-1C-D with P/AR Adapter.

The combined effect of Amplitude Distortion, Envelope Delay Distortion, and Return Loss is characterized by a single number, the P/AR reading.

A P/AR reading of 100 ± 2 indicates a high quality line in terms of the three properties mentioned above. As these properties grow more distorted, the P/AR reading will be lower. End-to-end P/AR is not a tarriffed parameter. A survey of the DDD network in 1982/83 and published in the *Bell System Technical Journal*, November, 1984 (Vol. 63, No. 9), shows cumulative distribution functions on long, medium, and short circuits. This curve indicates virtually no short circuits with a P/AR below 70 and that 50% of the circuits monitored have a P/AR greater than 80. Probably the most useful application of P/AR in private line is to record a benchmark value when the circuit is up. Reading changes (either way) by more than 5 are an indication of a circuit change.

4-28. Operation with P/AR Adapter.

To operate the P/AR Adapter, connect the PB-1C-D OUTPUT to the transmit pair of the line under test and connect the receive pair to the PB-1C-D INPUT. Loop back the line under test and switch to the P/AR mode by throwing the P/AR/OSC switch to P/AR. The PB-1C-D will send a P/AR signal (value 100) on the transmit pair.

The PB-1C-D will read the looped-back P/AR signal and display the P/AR reading. To operate the PB-1C-D in its normal mode, throw the P/AR/OSC switch to OSC.

A self-test is provided for the P/AR adapter. With the P/AR/OSC switch in the P/AR position, press either one of the momentary switches labelled 80 and 100. By pressing the switch marked 100, the P/AR signal is internally looped back and should read 100 ± 2. By pressing the switch marked 80, the P/AR signal is internally looped back through a filter calibrated to produce a P/AR reading of 80. These tests can be done regardless of the PB-1C-D INPUT and OUTPUT connections. To operate the PB-1C-D in the normal mode, throw the P/AR/OSC switch to OSC.

4-29. SELF-CHECK OF PB-1C-D

The following steps constitute a self-check procedure. This self-check procedure should be employed for initial checkout of the PB-1C-D immediately after receiving and unpacking the instrument. It should also be employed whenever anomalous behavior or malfunction occurs, but only after possibility of operator error has been investigated and eliminated.

NOTE:

Any optional external equipment attached to the PB-1C-D must be disconnected or turned off before any checks of the PB-1C-D are peformed. The normal operation of the OUTPUT OSCILLATOR, for example, will be affected by such add-ons as the P/AR or the NNE Sequencer.

The P/AR unit must be switched to the OSC mode before PB-1C-D self-checks are performed. If the P/AR is left in the P/AR mode, the P/AR signal will be present at the PB-1C-D OUTPUT and sync cannot be obtained.

The NNE Sequencer must be switched to OFF before any PB-1C-D self-checks are performed. If the NNE Sequencer is left in the ENABLE mode, the NNE Sequencer will attempt to sequence through its automatic test cycle. The results will be unpredictable unless actually connected to a line under test (see BRTM Operating Manual #IN4140-684).

a. Start-Up

1. Set POWER switch to OFF. Plug female end of power cable into recessed male receptacle on left side of the PB-1C-D, plug male end of power cable into a 115Vac/60Hz single-phase grounded outlet, and patch OUTPUT jack to INPUT jack.

2. Set NNE switch to NORMAL, 600Ω/BRIDGE switch to 600Ω, HOLD COIL switch to OUT, SPEAKER MODE switch to INPUT. Depress OSCILLATOR OUTPUT FREQUENCY 1000Hz button and METER MODE LEVEL button. Rotate SPEAKER VOLUME control to its ccw stop, and rotate oscillator OUTPUT LEVEL control cw ¾ turn.

3. Set POWER switch to ON. The DO NOT READ CRT & RED FUNCTIONS indicator should light and go out after a few seconds. The frequency meter should then indicate approximately 1004Hz, the multi-mode meter and the INPUT LEVEL meter should both indicate between 5 and 10dBm, and the speaker output should be the 1004Hz tone.

4. Depress CRT MODE 4 TO 300Hz button and SCALE MULT −20dB/X0.5 button. Adjust SCALE ILLUM control to setting at which graticule illumination is visible, but at which scattered light from graticule does not increase background light level on CRT screen. Adjust INTENSITY and FOCUS controls for sharpest spot on CRT screen. Spot should be within smallest circle; i.e., spot deflection should be less than −50dB (sum of −30dB of smallest circle and −20dB SCALE MULT setting).

b. 1004Hz Checks

1. Slowly rotate OUTPUT LEVEL control to its ccw stop. Note that, unless rotation is very slow, CRT spot jumps up and down while OUTPUT LEVEL control is rotated. This reflects time required for the AGC loop to adjust to change in input level. There may also be some noise generated by the rotating arm of the potentiometer. The multi-mode and INPUT LEVEL meter indications should decrease together to −35dBm or less at ccw stop of OUTPUT LEVEL control. Speaker output should decrease until it becomes inaudible. At low levels, with the SPEAKER MODE switch set to NOTCH, the 60Hz power-frequency background noise becomes significant, and may be heard as a buzzing sound if the REMOVE FILTER BUTTON is depressed. Frequency meter indication should remain at 1004Hz.

2. Adjust OUTPUT LEVEL control for approximately 0dBm on multi-mode and INPUT LEVEL meters. Speaker output should become audible again. Read frequency meter and multi-mode meter. Hold down OUTPUT FREQ & LEVEL button and read both meters again. Frequency meter reading should not change at all; multi-mode meter reading should not change more than .3dB.

3. Slowly increase SPEAKER VOLUME until 1004Hz tone is fairly loud, then set SPEAKER MODE switch to NOTCH. Speaker output should become very low.

4. Gain Steps

a) Depress SCALE MULT +6dB/X10 button. Generate a positive gain step by setting the 600Ω/BRIDGE switch to BRIDGE. CRT spot should jump upward and quickly return to center. Speaker output should be a 'ping'. Multi-mode and INPUT LEVEL meter indications should increase from 0dBm to +6dBm.

b) Generate a negative gain step by setting the 600Ω/BRIDGE switch to 600Ω. CRT spot should jump downward and quickly return to center. Speaker output should be a 'ping'. Multi-mode and INPUT LEVEL meter indications should return to 0dBm.

c) Depress CRT MODE UNFILT button, and repeat 4a). Note that, instead of the CRT spot jumping up and quickly returning to center, a circle tangent to the horizontal axis forms above that axis and then collapses. Increase INTENSITY setting, if necessary.

d) With the CRT MODE UNFILT button depressed, repeat 4b). Note that instead of the CRT spot jumping downward and quickly returning to center, a circle tangent to the horizontal axis forms below that axis and then collapses.

5. Phase Steps

a) Depress CRT MODE 4 TO 300Hz button and SCALE MULT −20dB/X0.5 button. Set SPEAKER MODE switch to NOTCH. Generate a negative phase step by setting the HOLD COIL switch to IN. CRT spot should deflect to left and then return to center. Speaker output should be a 'ping'.

b) Generate a positive phase step by setting the HOLD COIL switch to OUT. CRT spot should deflect to right and then return to center. Speaker output should be a 'ping'.

c) With the CRT MODE UNFILT button depressed, generate a negative phase step by setting the HOLD COIL switch to IN. Note that instead of CRT spot jumping to left and returning to center as in b) above, a circle tangent to the vertical axis forms to left of vertical axis and then collapses towards the vertical axis.

d) Depress CRT MODE UNFILT button and generate a positive phase step by setting the HOLD COIL switch to OUT. Note that instead of CRT spot jumping to right and returning to center, a circle tangent to vertical axis forms to right of vertical axis and collapses.

6. Comparison of dBm, dBrnC, and dBrn Levels

a) With LEVEL button depressed, adjust OUTPUT LEVEL control for approximately −30dBm on multi-mode meter.

b) Depress NOISE button. Multi-mode meter in-

dication should change to approximately 60dBrnC, since dBrnC = dBm + 90.

c) Hold down REMOVE FILTER button. NOISE reading may increase 0.1 to 0.2dB, depending on local grounding. Since C-Message filter has been removed, the NOISE reading is no longer in dBrnC but in dBrn.

c. 1004 + 2008Hz Checks

1. Depress OSCILLATOR OUTPUT FREQUENCY 1000 + 2000Hz button. The oscillator output is now a 1004Hz 'fundamental', with a 2008Hz 'second harmonic' that is 10dB down from the 1004Hz level set by the OUTPUT control. The input circuits will lock to the 1004Hz tone, the DO NOT READ lamp will go out, and a four-leaf pattern will appear at the center of the screen. The frequency meter should indicate 1004 ± 2Hz.

2. Comparison of LEVEL, NOISE, and NN SEP

a) Depress LEVEL button and adjust OUTPUT LEVEL control for −30dBm indication on multi-mode meter.

b) Depress NOISE button. Multi-mode meter indication should change to approximately 60dBrnC.

c) Depress NN SEP button and REMOVE FILTER button. Multi-mode meter indication should be approximately −10dB, which is the level of the 2008Hz notched noise relative to the 1004Hz tone. When REMOVE FILTER button is released, multi-mode meter indication should decrease to −11.3 ± 1dB. Note: As REMOVE FILTER button is depressed or released a hit will be displayed on CRT due to the 200Hz HIGH PASS filter being switched. This is not a line hit.

3. Set SPEAKER MODE switch to INPUT; the speaker output should be 1004Hz tone with 31.6% 2008Hz second harmonic. Set SPEAKER MODE switch to NOTCH; the speaker output should be a 2008Hz tone.

4. Depress CRT MODE 4 TO 20Hz and SCALE MULT −20/X0.5 buttons. CRT spot should be at center.

5. Depress CRT MODE 20 TO 300Hz button. The CRT spot should become a nominally −50dB circle indicating that the 20 to 300Hz filter (whose upper limit is 300Hz above the 1004Hz tone) has attenuated the −10dB, 2008Hz 'second harmonic' by approximately 40dB relative to the 1004Hz 'fundamental'.

6. Depress CRT MODE 4 TO 300Hz button. The SFI circle diameter should remain about −50dB as in previous step, indicating that the 4 to 300Hz filter has attenuated the −10dB, 2008Hz 'second harmonic' by 40dB relative to the 1004Hz 'fundamental'.

7. Depress CRT MODE UNFILT button. The CRT display should change and expand so that its extremes are off screen. (It may be necessary to increase INTENSITY setting). Successively depress SCALE MULT −14dB/X1, −8dB/X2, 0dB/X5, and +6dB/X10 buttons until, at the last setting, a complete four-leaf clover appears on the CRT screen.

a) Note that the maximum diameter of the cloverleaf is −16dB (the graticule scale calibration) +6dB (the SCALE MULT setting) = −10dB.

b) Check vertical and dimensions of the four-leaf clover by setting SINGLE-AXIS switch to VERT and then to HOR.

c) Set NNE switch to ATTEN. SCALE CHANGE ON RED FUNCTIONS indicator should flash, and diameter of four-leaf clover should decrease 14dB. Check this reduction by depressing the SCALE MULT −8dB/X2 button, which should restore the cloverleaf to its original size. Set NNE switch to NORMAL and SCALE MULT switch to +6dB/X10.

8. Depress CRT MODE 2ND H button. CRT spot should deflect in some direction to the −16dB circle. The value of the deflection will be −16dB + 6dB = −10dB. Confirm this by holding down the HARMONIC SEPARATION button; the multi-mode meter should read approximately −10dB.

d. 2008Hz Check. Set OUTPUT LEVEL control to cw stop and depress OSCILLATOR OUTPUT FREQUENCY 2000Hz and METER MODE LEVEL buttons. The DO NOT READ indicator should light and the CRT spot should be deflected downward off screen, because there is no tone in the range 930 to 1030Hz for the input circuits to lock to. Frequency meter and speaker output (with SPEAKER MODE switch in either NOTCH or INPUT positions) should both indicate 2008Hz.

e. 2713Hz Check. Depress OSCILLATOR OUTPUT FREQUENCY 2713Hz button. The DO NOT READ indicator should remain lit, and the CRT spot should remain deflected off screen, because there is no 930 to 1030Hz tone for the input circuits to lock on to. Frequency meter indication and speaker output (with SPEAKER MODE switch in either NOTCH or INPUT positions) should both be 2713Hz.

f. 200 TO 5000Hz VAR Check

1. Rotate 200 TO 5000Hz control to ccw stop, and depress OSCILLATOR OUTPUT FREQUENCY VAR button. Frequency meter and speaker output (in either INPUT or NOTCH MODE) should both indicate 200Hz or less. CRT spot should be off screen and DO NOT READ CRT & RED FUNCTIONS indicator should be lit, because there is no 930 to 1030Hz tone for the input circuits to lock to.

2. Slowly rotate 200 TO 5000Hz control clockwise, noting increasing frequency on frequency meter and in speaker output. Note that at about 930Hz, input circuits lock to oscillator output, DO NOT READ indicator goes out, CRT spot jumps to center of screen, and speaker output (with SPEAKER MODE switch set to NOTCH) drops sharply. Continue rotating 200 TO 5000Hz control slowly cw. Note that at about 1030Hz, input circuits can no longer remain locked to oscillator output, DO NOT READ indicator lights, CRT spot is deflected downward off screen, and SPEAKER NOTCH MODE output increases sharply. Continue rotation and observe upper frequency limit of approximately 5000Hz.

g. Oscillator Level Checks

1. Depress OSCILLATOR OUTPUT FREQUENCY 1000 button and METER MODE LEVEL button, and set OUT-

PUT LEVEL control for an indication of 0dBm on the multi-mode meter.

2. Depress OSCILLATOR OUTPUT FREQUENCY 2000 button. The multi-mode meter should indicate a 2008Hz tone level of 0.0 ± 0.2dBm.

3. Depress OSCILLATOR OUTPUT FREQUENCY 2713Hz button. The multi-mode meter should indicate a 2713Hz tone level of 0.0 + 0.2dBm.

4. Depress OSCILLATOR OUTPUT FREQUENCY 1000 + 2000 button. The multi-mode meter should indicate a 1004 + 2008Hz tone level of − 0.2 ± 0.2dBm.

5. Depress OSCILLATOR OUTPUT FREQUENCY VAR button and slowly rotate the 200 TO 5000Hz control to its cw and ccw stops. The multi-mode meter indication should be 0.0 ± 0.2dBm above 350Hz. Below 350Hz the level will fall off as the frequency decreases unless REMOVE FILTER button is depressed.

h. Amplitude Jitter and Phase Jitter Checks require the use of a calibrated source of jitter or of single-frequency interference. The procedures for checkout and alignment of the amplitude and phase jitter measuring circuits are described in Par. 5-16 and 5-17.

SECTION V
ALIGNMENT

5-1. GENERAL

a. The measuring and display circuits of the PB-1C-D should be aligned only if they drift out of their specified operating limits. To find whether any circuits need to be aligned, perform the self-checking procedures of Par. 4-27. Those procedures will determine, for each measuring and display circuit, whether it is :

1. within specifications, and needs no alignment;

2. out of specifications by a gross amount (usually resulting from malfunction), and requires factory repair and alignment;

3. out of specifications by a small amount (usually resulting from drift), and alignable in the field by the procedures described in this section.

b. The alignment procedures of this section should be performed only by personnel familiar with the operation of the PB-1C-D and with the appearance of its displays.

c. NOTE: The PB-1C-D must be turned on and warmed up for at least 30 minutes before alignment, to permit the internal temperatures to stabilize.

5-2. EQUIPMENT REQUIRED FOR ALIGNMENT

The internal test tone oscillator, digital frequency meter, digital multi-mode meter, and phasor-domain CRT display provide the PB-1C-D with a wide range of self-testing capabilities so that, after any circuit is aligned, it can be used where applicable for subsequent alignment procedures. However, all alignment procedures can be peformed by means of the external test equipment listed below.

a. Oscillator -1: frequency range 300 to 3000Hz; output level range −35dBm to +10dBm; output impedance 600 ohms ±2%, balanced; phase jitter less than 0.1°; amplitude jitter less than 0.1%; total distortion less than 1% (−35dB). Frequencies must be settable within 0.1% and output levels must be settable within 0.05dB. The TONE FREQUENCY oscillator of the Bradley Telcom 2A/2B Line Simulator meets these specifications.

b. Oscillator -2: Identical to oscillator **#**1 except for 1 to 3000Hz frequency range. The MODULATION FREQUENCY oscillator of the 2A/2B Line Simulator meets these specifications.

c. Level Meter accurate to 0.05dBm at 0dBm and −20dBm.

d. DC Oscilloscope

e. High-Impedance DC Voltmeter: input impedance 20,000Ω/V minimum.

f. Miscellaneous: patch cords, leads, card extender, rubber gloves, tools, etc., as required.

5-3. NOTES ON USE OF SFI FOR ALIGNMENT

a. Some PB-1C-D alignment procedures employ oscillator **#**1 as a source of test tones and oscillator **#**2 as a source of single-frequency interference (SFI) tones. SFI is a simple way to generate known amounts of amplitude jitter (which is equivalent to the in-phase component of SFI) and phase jitter (which is equivalent to the quadrature component of SFI). If the SFI level in dB relative to the test tone level is known, the amplitude jitter and the peak-to-peak phase jitter caused by the SFI can be calculated from the following equations:

$$\text{Percent Amplitude Jitter} = 100\left[10^{\frac{-\text{dB of SFI}}{20}}\right]$$

$$\text{Degrees of Phase Jitter} = 2\arcsin\left[10^{\frac{-\text{dB of SFI}}{20}}\right]$$

For example the values of amplitude jitter and phase jitter corresponding to an SFI tone at −20dB relative to the test tone are 10% and 11.5°, respectively.

b. If the 2A/2B Line Simulator is available, if the TONE FREQUENCY oscillator is used to provide the test tone, and if the MODULATION FREQUENCY oscillator is used to provide the SFI tone, the SINGLE FREQUENCY INTERFERENCE level control setting will give percent SFI directly with respect to the 2A/2B OUTPUT LEVEL control setting, e.g., a SINGLE FREQUENCY INTERFERENCE level setting of 31.6% will give an SFI level of −10dB with respect to the 2A/2B OUTPUT LEVEL setting. Furthermore, the two tones are added internally in the 2A/2B Line Simulator, and their sum appears at a single 600-ohm output. If this output is patched to the PB-1C-D INPUT jack and the PB-1C-D INPUT switch is set to 600Ω, then the 2A/2B Simulator and the PB-1C-D Analyzer will be properly matched, and the output levels of the two oscillators will be correct.

c. If the 2A/2B Line Simulator is not available, and oscillators **#**1 and **#**2 are separate units with their outputs paralleled at the PB-1C-D input jacks, the load impedance seen by either oscillator is equal to the input impedance of the PB-1C-D in parallel with the output impedance of the other oscillator. Since the output impedances of the oscillators are each 600 ohms, the PB-1C-D INPUT switch should be set to BRIDGE, so that each oscillator sees a 600-ohm load, and the output levels of **both** oscillators will correspond to the settings of their level controls. Note that before paralleling the outputs of the two oscillators, the level of each output should be measured separately with a properly-loaded level meter.

5-4. REMOVAL AND REPLACEMENT OF COVER

a. WARNING: HIGH VOLTAGE (−1100VDC) ACCESSIBLE WHEN COVER IS REMOVED. The high-voltage area inside the PB-1C-D is underneath the white rectangle on the cover.

b. To remove the cover for alignment, loosen and remove the eight screws which hold it in place, and lift the cover off. NOTE: To maintain stable interior temperatures during alignment, leave the unfastened cover in place except when making adjustments.

c. To replace the cover after alignment, fit it in place inside the top edges of the left, right and rear sides of the cabinet, and above the top edge of the front panel. Line up the hole in the front edge of the cover with the corresponding threaded hole in the bracket fastened to the top rear of the front panel, and start the screw. Alternating from left to right and going from front to rear, start the six screws along the side edges of the cover. Then start the screw in the rear edge. Finally, tighten all eight screws.

5-5. LOCATIONS OF ADJUSTMENTS

a. All of the circuits in the PB-1C-D are mounted on printed-wiring boards or cards, the locations and orientations of which are given in Figure 5-1. All circuit adjustments are accomplished by means of small rectangular screwdriver-adjustable trim potentiometers mounted on the circuit boards. Figures 5-2 through 5-9 show the locations and orientations of the trim potentiometers on those boards requiring alignment. Note that the trim potentiometers may be mounted either parallel or perpendicular to the planes of their boards, as required for accessibility. Easily-accessible trim potentiometers are mounted parallel to the planes of their boards, so that they can be adjusted by means of a screwdriver held approximately perpendicular to the boards. Less-accessible trim potentiometers, such as those on closely-spaced parallel vertical boards, are mounted perpendicular to their boards so that they can be adjusted by means of a vertically-held screwdriver inserted between the boards.

b. The largest board (Figure 5-2) is the mother board, which is mounted horizontally just above the bottom of the instrument. The other boards are plugged into or otherwise connected to the mother board, which supplies power to the boards and provides interconnections between the boards.

c. The oscillator card (Figure 5-3) is mounted horizontally just above the mother board, and the meter card (Figure 5-4) is mounted horizontally above the oscillator card. Although the meter card partially obscures the oscillator card, and both partially obscure the mother board, the trim potentiometers on all three boards are located so that they are directly accessible to a vertically-held screwdriver.

d. The display card (Figure 5-5) is mounted vertically just behind two windows at the top left of the front panel, and plugs into a connector at the front of the meter card. The two trim potentiometers on the display card are accessible through two small holes at the left of the top window.

e. All of the remaining circuit boards are mounted vertically, and most of them plug into connectors on the mother board. The boards containing trim potentiometers are shown in Figures 5-6 through 5-9. The HV card (Figure 5-6) is mounted at the rear; and all of its trim potentiometers are adjustable by means of an approximately horizontal screwdriver. Most of the trim potentiometers on the dB card (Figure 5-7), the output card (Figure 5-8) and the NPLL card (Figure 5-9) are adjustable by means of a vertically-held screwdriver inserted between the cards; some other adjustments on those cards may require the use of an extender board inserted between each card and its connector on the mother board. The dB and output cards are fastened to support brackets by means of screws through holes at their upper rear corners, and the NPLL card is fastened to a support bracket by means of a screw through a hole in its upper front corner. To use an extender board with any one of these cards, the retaining screw must first be removed to permit unplugging the card. Note that the NPLL has a keying slot, and that the NPLL connector has a corresponding 'key' to prevent the card from being inserted incorrectly. The 'key' must be removed from the connector when using the extender board with the NPLL card, and should be replaced afterward. Some cards are insulated from their support brackets by Teflon washers, which must be saved when the cards are removed, and re-used when the cards are refastened in place.

5-6. FREQUENCY METER CHECK

The digital frequency meter has no adjustments. It is crystal-controlled so that the frequency display is accurate within ±2Hz under all normal operating conditions. Check the operation of the frequency meter as follows:

a. Patch PB-1C-D OUTPUT jack to INPUT jack, and connect external 600Ω level meter across INPUT. Set INPUT switch to BRIDGE.

b. Set the oscillator OUTPUT LEVEL control for 0dBm on the external level meter, and slowly rotate the 200 TO 5000Hz control to its cw and ccw stops. The internal frequency meter indications should be less than 200Hz at the ccw stop, and more than 5000Hz at the cw stop. The REMOVE FILTER button may have to be pressed to read frequencies below 200Hz.

5-7. FAST INPUT LEVEL METER ADJUSTMENTS
(Mother Board)

a. Patch the output of oscillator #1 to the PB-1C-D INPUT jack and also to the input of the external level meter. Set the PB-1C-D INPUT switch to 600Ω, and set the HOLD COIL switch to OUT.

b. Set Oscillator #1 output to 0dBm at 1000Hz, and observe the INPUT LEVEL meter. The 0dBm bar should be brightly lit, and the adjacent −3dBm and +3dBm bars should be dimmer but of equal intensity to each other. If required, set high-end adjustment P1 on the mother board to achieve the desired results.

c. Set oscillator #1 output to −30dBm at 1000Hz. The −30dBm bar should be brightly lit, and the adjacent −27dBm and −33dBm bars should be dimmer but of equal intensity to each other. If required, set low-end adjustment P2 on the mother board to achieve the desired results.

d. The settings of P1 and P2 are slightly interactive. Therefore, repeat steps b. and c. until no further adjustments of P1 and P2 are required.

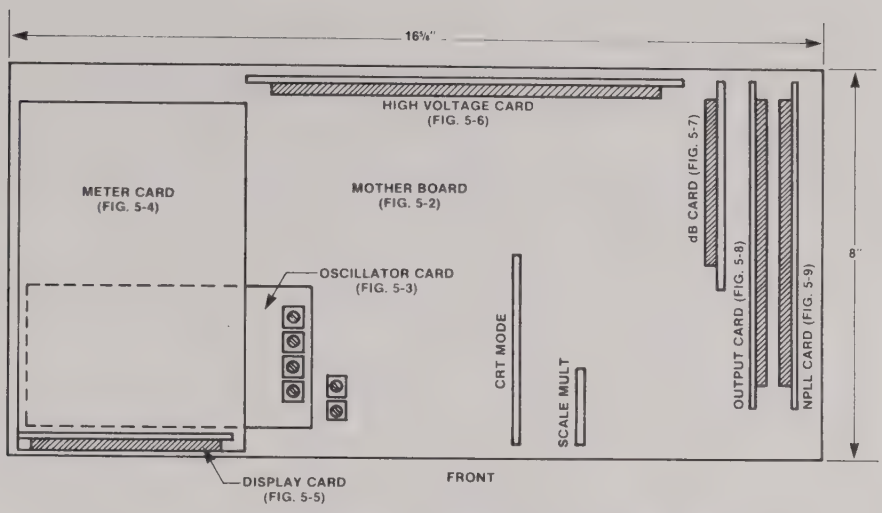


FIG. 5-1 LOCATIONS OF CIRCUIT BOARDS IN PB-1C-D

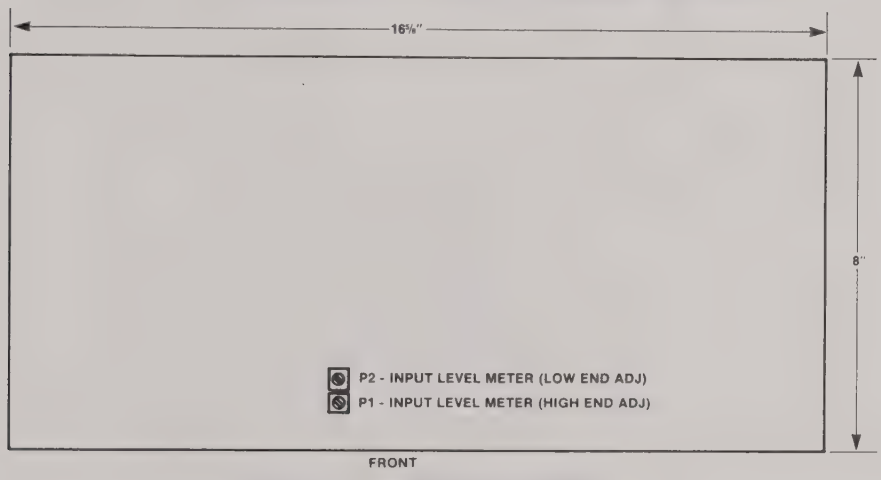


FIG. 5-2 MOTHER BOARD

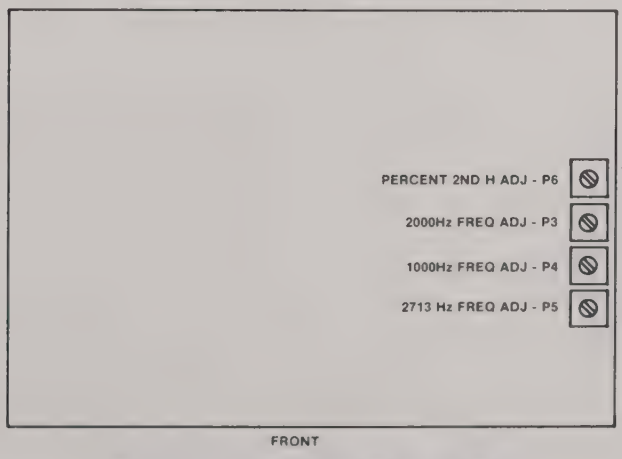


FIG. 5-3 OSCILLATOR CARD

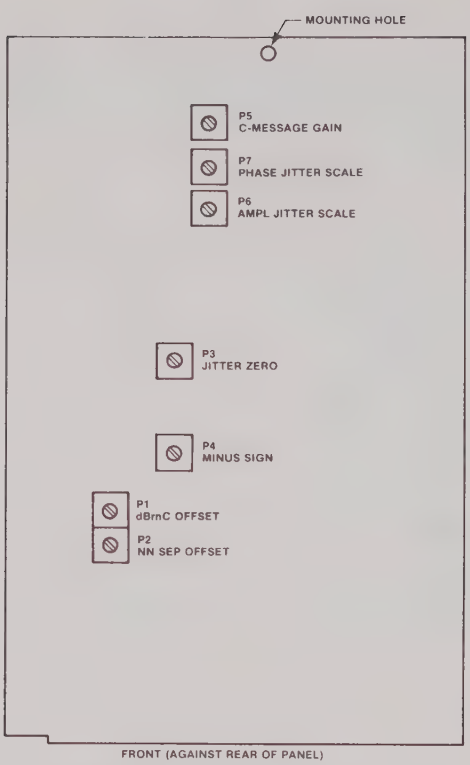


FIG. 5-4 METER CARD

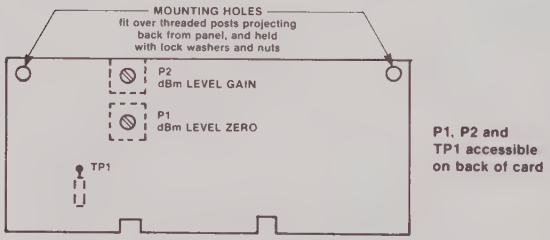


FIG. 5-5 DISPLAY CARD

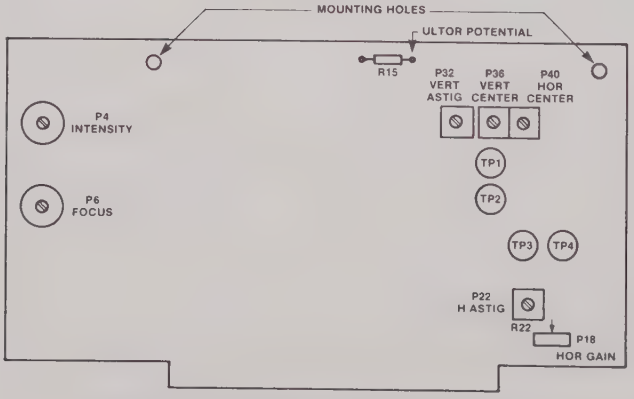


FIG. 5-6 HIGH VOLTAGE CARD

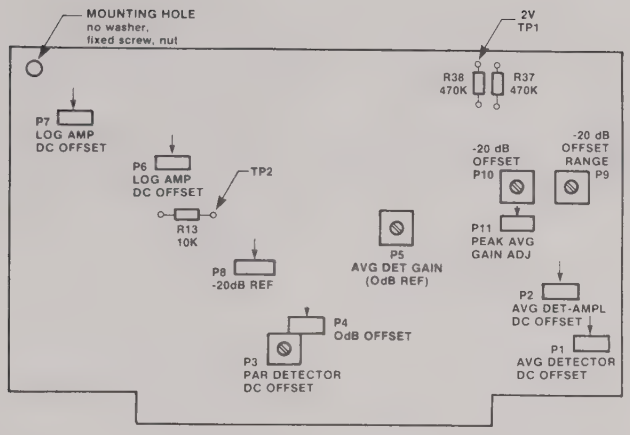


FIG. 5-7 dB CARD

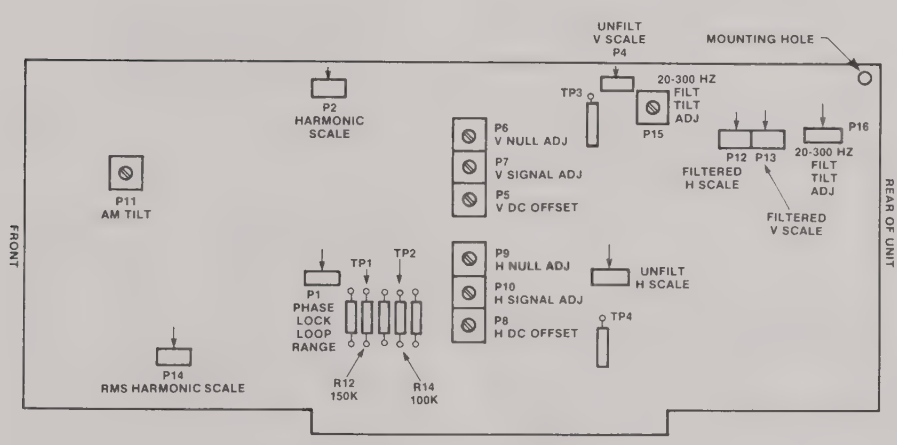


FIG. 5-8 OUTPUT CARD

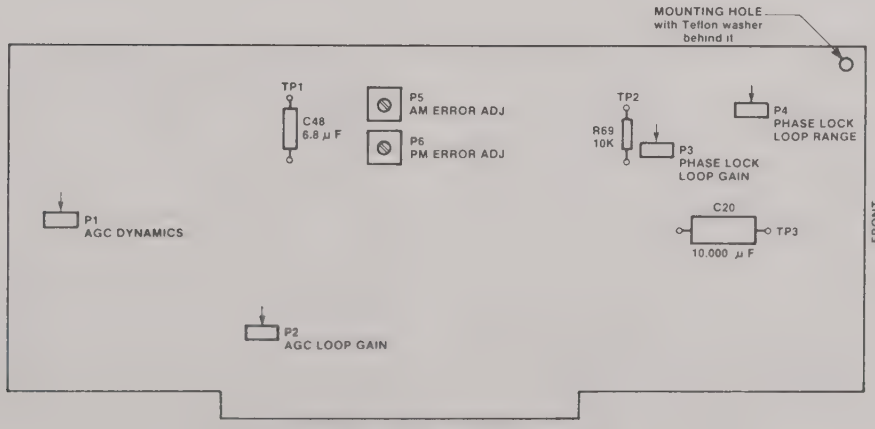


FIG. 5-9 NPLL CARD

e. Check the INPUT LEVEL meter over its range by rotating the oscillator #1 output level control to its ccw and cw stops.

5-8. OSCILLATOR FREQUENCY ADJUSTMENTS (Oscillator Card)

a. Patch PB-1C-D OUTPUT to PB-1C-D INPUT, and also to input of external level meter. Set PB-1C-D INPUT switch to 600Ω, and set HOLD COIL switch to OUT.

b. 1004Hz Adjustment. Depress OSCILLATOR OUTPUT FREQUENCY 1000Hz button, and set OUTPUT LEVEL control for 0dBm on external level meter. The frequency meter should indicate 1004 ± 2Hz. If required, set P4 on the oscillator card to give 1004 ± 2Hz.

c. 2008Hz Adjustment. Depress the 2000Hz button. The frequency meter should indicate 2008 ± 2Hz. If required, set P3 on the oscillator card to give 2008 ± 2Hz. The output level should be within ± 0.2dBm of the 1004Hz level.

d. 2713Hz Adjustment. Depress the 2713Hz button. The frequency meter should indicate 2713 ± 2Hz. If required, set P5 on the oscillator card to give 2713 ± 2Hz. The output level should be within ± 0.2dBm of the 1004Hz level.

e. 200 TO 5000Hz Frequency Range Check. The 200 to 5000Hz range has no adjustments. To check the frequency range depress the OSCILLATOR OUTPUT FREQUENCY VAR button and rotate the 200 TO 5000Hz control to its ccw and cw stops. The frequency meter should indicate a lowest frequency below 200Hz and a highest frequency above 5000Hz. The output level should remain within ± 0.2dBm of the 1004Hz level over the entire frequency range.

f. Percent Second Harmonic Adjustment. When the OSCILLATOR OUTPUT FREQUENCY 1000 + 2000 button is depressed, the signal at the OUTPUT jack is 1004Hz with 31.6% second harmonic, i.e., 1004Hz with 2008Hz at − 10dB relative to the 1004Hz tone. Trim potentiometer P6 on the oscillator card adjusts the 2008Hz level relative to the 1004Hz level. This adjustment should be made in accordance with the procedure of Par. 5-15c.3.

5-9. MULTI-MODE METER ADJUSTMENTS

Note that the METER MODE LEVEL and NOISE buttons are black, while the NN SEP, AMPL. JITTER and PHASE JITTER buttons are red. The LEVEL and NOISE modes can therefore be used whether the DO NOT READ CRT AND RED FUNCTIONS indicator is on or off, but the NN SEP, AMPL. JITTER and PHASE JITTER modes can be used only when the DO NOT READ INDICATOR is off, because they employ voltages from the CRT phasor-domain circuit. The CRT circuits must therefore be aligned before the NN SEP, AMPL. JITTER and PHASE JITTER modes.

5-10. LEVEL Mode Adjustments (dB Card)

a. Patch the PB-1C-D OUTPUT jack to the PB-1C-D INPUT jack, and to the input of the external level meter. Set the PB-1C-D INPUT switch to 600Ω and the HOLD COIL switch to OUT, and depress the METER MODE LEVEL button.

b. Depress the OSCILLATOR OUTPUT FREQUENCY 1000Hz button and set the OUTPUT LEVEL control for 0.0dBm on the external level meter. The multi-mode meter should indicate 0.0 ± 0.1dBm; if it does not, but is within 0.0 ± 0.5dBm, adjust P4 on the dB card in small increments, waiting between increments to give the correction circuit time to compensate, until the multi-mode meter indicates 0.0 ± 0.1dBm.

c. Set the OUTPUT LEVEL control for − 20.0dBm on the external level meter. The multi-mode meter should indicate − 20.0 ± 0.2dBm; if it does not, but is within − 20 ± 1.0dBm, adjust P10 on the dB card until the multi-mode meter indicates − 20.0 ± 0.2dBm.

d. Set the OUTPUT LEVEL control for − 40dBm on the external level meter. The multi-mode meter should indicate − 40.0 ± 0.5dBm, if it does not, but is within − 40.0 ± 2.5dBm, adjust P2 on the dB card until the multi-mode meter indicates − 40.0 ± 0.3dBm.

e. Repeat step b; readjust P4 if required.

f. Repeat step c; readjust P10 if required.

g. Repeat step d; readjust P2 if required.

5-11. NOISE Mode Adjustments (Meter Card)

a. Check that the PB-1C-D OUTPUT jack is patched to the INPUT jack, the INPUT switch is set to 600Ω, and the HOLD COIL switch is set to OUT.

b. C-Message Filter Gain Adjustment. Depress OSCILLATOR OUTPUT FREQUENCY 2000Hz button.

1. Depress METER MODE LEVEL button, and set OUTPUT LEVEL control for − 30dBm on multi-mode meter.

2. Depress METER MODE NOISE button, and note multi-mode meter reading.

3. With METER MODE NOISE button depressed, depress also the REMOVE FILTER button. The multi-mode meter reading should increase by 1.3 ± 0.5dB. If it does not, note the reading with the REMOVE FILTER button depressed, then release REMOVE FILTER button and adjust P5 on the meter card so that the reading with the REMOVE FILTER button released is 1.3 ± 0.5dB below the reading with the REMOVE FILTER button depressed. NOTE: Since C-Message filter gain adjustment P5 is in the C-Message filter circuit, the effect of adjusting P5 can be seen on the multi-mode meter during such adjustments only when the REMOVE FILTER button is released.

c. NOISE Mode Scale Adjustment and Checks. Depress OSCILLATOR OUTPUT FREQUENCY 1000Hz button.

1. Depress METER MODE LEVEL button and set OUTPUT LEVEL control for − 30.0dBm on multi-mode meter.

2. Depress METER MODE NOISE button. The multi-mode meter should indicate 60.0 ± 0.2dBrnC (i.e., dBrnC = dBm + 90). If it does not, but is within 60.0 ± 0.5dBrnC, adjust P1 on meter card so that multi-mode meter indicates 60.0 ± 0.2dBrnC.

3. Depress METER MODE LEVEL button and set OUTPUT LEVEL control for −15.0dBm on multi-mode meter. Then depress METER MODE NOISE button. The multi-mode meter should indicate 75.0±0.5dBrnC.

4. Depress METER MODE LEVEL button and set OUTPUT LEVEL control for −40.0dBm. Then depress METER MODE NOISE button. The multi-mode meter should indicate 50±0.5dBrnC.

5-12. CRT TILT, CENTERING, AND ASTIGMATISM (High-Voltage Card)

a. Patch the PB-1C-D OUTPUT jack to the PB-1C-D INPUT jack, and depress the OSCILLATOR OUTPUT FREQUENCY 1000+2000HZ button, the CRT MODE UNFILT button and the SCALE MULT X5 button. (The settings of the INPUT and HOLD COIL switches are unimportant.) A four-leaf pattern should fill the screen, and may even extend somewhat beyond the edges of the screen.

b. Hold the SINGLE AXIS switch in the VERT position. The four-leaf pattern should collapse to a vertical trace, i.e., parallel to the vertical axis of the graticule. If the trace is tilted with respect to the vertical axis, the CRT must be rotated to make the trace parallel to the vertical axis, as explained in step d. below.

c. DANGER: −1100VDC ON HV CARD AND CRT CONNECTOR. Touch only with insulated tools and rubber gloves.

d. CRT Tilt Adjustment. A conical metal shield surrounds all of the CRT except for a small section of the CRT neck and the CRT base which extend from the rear of the shield. The CRT base is plugged into a socket connected by wires to the high-voltage card. The CRT is fastened to the shield by a clamp around the exposed section of the neck. To adjust the tilt of the CRT, put on rubber gloves, open the clamp, grasp the CRT socket connector, and rotate the CRT until the vertical trace (with SINGLE AXIS switch held at VERT) is parallel to the graticule vertical axis. Press the socket connector forward so that the front of the CRT is firmly seated in its bezel, and tighten the clamp. To ascertain that tightening the clamp has not altered the tilt adjustment, hold the SINGLE AXIS switch to VERT, and check that the CRT trace is still parallel to the graticule vertical axis.

e. Horizontal Centering. Although the tilt adjustment has made the CRT vertical trace parallel to the graticule vertical axis, the trace may be offset from that axis. If, with the SINGLE AXIS switch set to VERT, the vertical trace is offset from the vertical axis, set horizontal centering adjustment P40 on the HV card so that the vertical trace becomes coincident with the vertical axis.

f. Vertical Centering. Hold the SINGLE AXIS switch at HOR. The four-leaf pattern will collapse to a horizontal trace parallel to the graticule horizontal axis. If the horizontal trace is offset from the horizontal axis, set vertical centering adjustment P36 so that the horizontal trace becomes coincident with the horizontal axis.

g. Vertical Deflection Saturation Adjustment. Depress the SCALE MULT X2 button and observe four-leaf pattern. If there is any clipping or distortion of top or bottom edges of pattern, adjust P32 on HV card to obtain least clipping and distortion.

h. Astigmatism. Adjust FOCUS so that top and bottom edges of four-leaf pattern are in focus. Then adjust P22 so that right and left edges of pattern are also in focus. If adjustment of P22 changes overall focus, readjust FOCUS and P2 alternately until astigmatism is eliminated.

5-13. VECTOR NOTCH CHECKS AND ADJUSTMENTS (NPLL Card)

The normalized notched noise voltage which appears between tip and ground of the INTERCONNECT B jack is useful for the following PB-1C-D checks and alignment procedures.

a. Vector Notch Lock-In Range. The DO NOT READ indicator will be off when the AGC loop, the notch phase-lock loop (NPLL) and the display phase-lock loop (DPLL) are all locked to their input signals; and will be on if any loop is not locked to its input signal. If the DO NOT READ indicator goes on in response to input frequency variations, either the NPLL or the DPLL may not be locked to the signal.

1. Patch PB-1C-D OUTPUT to INPUT. Depress OSCILLATOR OUTPUT FREQUENCY 1000Hz button, CRT MODE UNFILT button, and METER MODE LEVEL button. Slowly rotate PB-1C-D OUTPUT LEVEL control to its ccw and cw stops. DO NOT READ indicator should be off over the entire output level range.

2. Depress OSCILLATOR OUTPUT FREQUENCY VAR button, set 200 TO 5000Hz control for 1000Hz on the frequency meter, and set the PB-1C-D OUTPUT LEVEL control to its ccw stop. The DO NOT READ indicator should be off. Slowly rotate the 200 TO 5000Hz control cw until the DO NOT READ indicator lights. The internal frequency meter should indicate that the upper frequency limit f_H at which the DO NOT READ indicator lights is 1030Hz or greater.

3. Reset 200 TO 5000Hz control for 1000Hz on the frequency meter. The DO NOT READ indicator should be off. Slowly rotate the 200 TO 5000Hz control ccw until the DO NOT READ indicator lights. The frequency meter should indicate that the frequency f_L at which the DO NOT READ indicator lights is 930Hz or less.

4. If the DO NOT READ indicator does not remain off between 930 and 1030Hz (i.e., if the NPLL lock-in range does not extend from 930Hz to 1030Hz), connect a dc oscilloscope between TP2 on the NPLL card and any convenient PB-1C-D chassis ground. Synchronize the oscilloscope sweep to the input tone frequency, and select a vertical gain such that ±12Vdc deflections do not exceed the upper and lower edges of the oscilloscope graticule. When the DO NOT READ indicator is off and the NPLL and DPLL are locked to the input tone, the voltage at TP2 will be some dc voltage between ±12Vdc. (If the DO NOT READ indicator is on, but the oscilloscope indication at TP2 is a dc voltage between ±12Vdc, the NPLL is functioning properly, but the DPLL is not.)

5. Set the input frequency to 1004Hz. The DNR indicator will be off. Lower the input frequency until a stepped

sine wave appears on the oscilloscope connected to TP2, and (within 2 seconds) the DNR indicator goes on. Note this lower frequency limit, f_L.

6. Set the input frequency to 1004Hz. The DNR indicator will be off. Raise the input frequency until a stepped sine wave appears on the oscilloscope connected to TP2 and (within 2 seconds) the DNR indicator goes on. Note this upper frequency limit, f_H.

7. If the NPLL lock-in range ($f_H - f_L$)is correct (i.e., at least 100Hz wide) but f_H and f_L are not 1030Hz and 930Hz respectively, set the input frequency to 1030Hz and adjust P4 on the NPLL card so that the NPLL just synchronizes (as shown by the disappearance of the stepped sine wave and the appearance of approximately +11.5Vdc on the oscilloscope at TP2). Then lower the input frequency to 930Hz and check that the NPLL still synchronizes.

8. If the NPLL lock-in range is too narrow (i.e., $f_H - f_L$ is less than 100Hz), set the input frequency to f_H (i.e., the highest frequency at which the NPLL still synchronizes) and adjust P3 on the NPLL card to lower the TP2 dc voltage displayed on the oscilloscope.

9. Repeat steps 5 and 6 (to find the new values of f_H and f_L) and (if $f_H - f_L$ is still less than 100Hz) step 8, until the lock-in range $f_H - f_L$ is at least 100Hz, then repeat step 7 to shift the lock-in range so that it covers at least 930Hz to 1030Hz.

b. Vector Notch Null Adjustment. To check whether the Notch Phase-Lock Loop (NPLL) is operating properly, patch the PB-1C-D OUTPUT to the INPUT and connect the tip and ground of the INTERCONNECT B jack to an external level meter terminated with 600 ohms. Set the INPUT switch to 600Ω and the HOLD COIL switch to OUT. Depress the OSCILLATOR OUTPUT FREQUENCY 1000HZ button.

1. Slowly vary the OUTPUT LEVEL control over its range. The DO NOT READ indicator should remain off over the range, and the external level meter should indicate a notched noise level less than −50dBm over the range.

2. If the external level meter indicates a notched noise level greater than −50dBm at any input level between −30dBm and +10dBm, connect an external X-Y oscilloscope as follows: X to PB-1C-D INPUT jack (in parallel with 1004Hz input tone) and Y to test point TP1 on NPLL card. Set X gain for largest horizontal deflection that does not exceed edges of screen, and set Y gain to maximum. The trace will generally be a closed loop.

3. Adjust P5 on the NPLL card so that the area inside the loop is minimized; i.e., the loop becomes a line.

4. Adjust P6 on the NPLL card so that the line is horizontal. The external level meter should now indicate less than −50dBm when the OUTPUT LEVEL control is varied over its range.

c. Vector Notch Scaling Check.

1. If a 2A/2B Simulator is available, set 2A/2B TONE FREQUENCY to 1000Hz, MODULATION FREQUENCY to 1200Hz, SINGLE FREQUENCY INTERFERENCE CONTROL to 25.2% (−12dB), SINGLE FREQUENCY INTERFERENCE switch to ON, all other toggle switches to OFF, OUTPUT LEVEL to 0dBm and SOURCE IMPEDANCE to 600Ω. Patch 2A/2B OUTPUT to PB-1C-D INPUT. The external level meter should indicate −12.0±0.25dBm at the INTERCONNECT B jack tip to ground.

2. If a 2A/2B Simulator Is Not Available, patch the PB-1C-D OUTPUT to the INPUT and connect the tip and ground of the INTERCONNECT B jack to an external level meter terminated with 600 ohms. Set the INPUT switch to 600Ω, and the HOLD COIL switch to OUT. Depress the OSCILLATOR OUTPUT FREQUENCY 1000+2000Hz button. The external level meter should indicate −10.0±0.25dBm at the INTERCONNECT B jack tip to ground.

5-14. CRT DPLL Adjustments (NPLL, Output, and HV Cards)

a. DPLL Lock-In Range Adjustments. Patch PB-1C-D OUTPUT jack to INPUT jack, depress OSCILLATOR OUTPUT FREQUENCY VAR button, and slowly rotate 200 TO 5000Hz control over the frequency range from 930Hz to 1030Hz. DO NOT READ indicator should not light. If DO NOT READ indicator lights at any frequency between 930 and 1030Hz, adjust P1 on output card so that DO NOT READ indicator remains off in the 930 to 1030Hz range.

b. DPLL Notch Null Adjustment. Patch the PB-1C-D OUTPUT jack to the INPUT jack. Depress the OSCILLATOR OUTPUT FREQUENCY 1000Hz button, the CRT MODE UNFILT button, and the SCALE MULT X0.5 button. Adjust P6 and P9 on the output card to obtain the smallest CRT pattern.

c. Horizontal and Vertical Gain-Matching Adjustment. Patch the PB-1C-D OUTPUT jack to the INPUT jack, depress the OSCILLATOR OUTPUT FREQUENCY 1000Hz button, and set OUTPUT LEVEL to 0dBm. Set the external oscillator for 2000Hz at −12dBm, and patch the external oscillator output into the PB-1C-D INPUT jack in parallel with the PB-1C-D oscillator output. Depress the CRT MODE 2ND H and SCALE MULT X5 buttons.

1. Adjust the external oscillator frequency to obtain a CRT spot moving slowly in a circular path concentric with the center of the graticule. If the path of the spot is not circular, adjust P18 on the HV card to obtain a circular path.

2. Adjust P2 on output card so that circular path of spot matches the −12dB circle on the graticule.

d. DPLL UNFILTered Signal Level Adjustments.

1. Patch the PB-1C-D OUTPUT jack to the INPUT jack, depress the OSCILLATOR OUTPUT FREQUENCY 1000Hz button, and set the OUTPUT level to 0dBm. Set the external oscillator for 1200Hz at −12dBm, and patch the external oscillator output into the PB-1C-D INPUT jack in parallel with the PB-1C-D oscillator output.

2. Depress the CRT MODE UNFILT and SCALE MULT X5 buttons. The CRT display should be two superimposed concentric circular disc patterns. If the circular discs

are not concentric adjust P7 and P10 on the output card until the discs are concentric.

3. Adjust P3 and P4 on the output card so that the superimposed concentric discs match the −12dB circle on the CRT graticule.

e. DPLL Filtered Signal Level Adjustments. Patch the PB-1C-D OUTPUT jack to the INPUT jack, depress the OSCILLATOR OUTPUT FREQUENCY 1000Hz button, and set the OUTPUT LEVEL to 0dBm. Set the external oscillator for 1200Hz at −12dBm, and patch the external oscillator output into the PB-1C-D INPUT jack in parallel with the PB-1C-D oscillator output.

1. Depress the CRT MODE 4 TO 300 and the SCALE MULT X5 buttons. The CRT display should be a circular pattern. Adjust P12 and P13 on output card so that the circular pattern matches the −12dB circle on the graticule.

2. Set the external oscillator to 1400Hz at −12dBm. The CRT display should decrease in size but should remain circular. If the pattern does not remain circular, adjust P15 and P16 on the output card to make the pattern circular.

f. Amplitude Modulation Tilt Adjustment. Patch the PB-1C-D OUTPUT jack to the INPUT jack. Depress the OSCILLATOR OUTPUT FREQUENCY 1000 button and set the OUTPUT LEVEL to 0dBm.

1. Set the dc oscilloscope to the X-Y mode, and match the X and Y probe sensitivities. Set the X and Y gains both to 0.1V/cm.

2. Connect the X probe to TP3 on the NPLL card and connect the Y probe to TP2 on the output card. Adjust P11 on the output card to obtain a straight line inclined at 45° to the X and Y axes of the oscilloscope.

5-15. NN SEP Mode Adjustments (Meter Card and dB Card)

a. Patch PB-1C-D OUTPUT to PB-1C-D INPUT, set INPUT switch to 600Ω and HOLD COIL switch to OUT.

b. Notch Purity Check.

1. Depress OSCILLATOR OUTPUT FREQUENCY 1000Hz button and METER MODE LEVEL button, and set OUTPUT LEVEL control for 0dBm on multi-mode meter.

2. Depress METER MODE NN SEP button. The multi-mode meter should indicate a level below −50dBm.

c. 1004 + 2008Hz Adjustments.

1. Depress METER MODE LEVEL button. Patch the external oscillator output to the PB-1C-D INPUT jack. Set the external oscillator output level to −10dBm on the multi-mode meter.

2. Patch the PB-1C-D OUTPUT jack to the INPUT jack in parallel with the output of the external OSCILLATOR. Depress the OSCILLATOR OUTPUT FREQUENCY 1000Hz, METER MODE NN SEP, and REMOVE FILTER buttons. The multi-mode meter should indicate 10.0 ± 0.2dBm. If the multi-mode meter indication is not 10.0 ± 0.2dBm, set P2 on the meter card for −10dBm on the multi-mode meter.

3. Disconnect the external oscillator from the PB-1C-D INPUT jack, but leave the PB-1C-D OUTPUT jack patched to the INPUT jack. Depress the OSCILLATOR OUTPUT FREQUENCY 1000 + 2000 button, the METER MODE NN SEP button, and the REMOVE FILTER button. The multi-mode meter should indicate −10.0 ± 0.2dBm. If the meter does not indicate −10.0 ± 0.2dBm, adjust P6 on the oscillator card so that the multi-mode meter indicates −10.0dBm.

4. With the 1000 + 2000Hz button, the NN SEP button and the REMOVE FILTER button all depressed, set the NNE switch to ATTEN. The multi-mode meter should indicate −24.0 ± 0.3dB. If the multi-mode meter does not indicate −24.0 ± 0.3dB, adjust P3 on the dB card so the multi-mode meter indicates −24.0 ± 0.3dB.

5-16. AMPL. JITTER Mode Adjustments (Meter Card)

a. If 2A/2B Line Simulator Is Available:

1. Set 2A/2B TONE FREQUENCY to 1000Hz, MODULATION FREQUENCY to 150Hz (modulation frequency range switch to X1), OUTPUT LEVEL to 0dBm, SOURCE IMPEDANCE to 600Ω, AMPLITUDE MODULATION switch to ON, all other 2A/2B toggle switches to OFF. Patch 2A/2B OUTPUT to PC-1C-D INPUT. Set PB-1C-D INPUT switch to 600Ω and HOLD COIL switch to OUT.

2. Depress PB-1C-D METER MODE AMPL. JITTER button. Set 2A/2B AMPLITUDE MODULATION control to 20%. Multi-mode meter should indicate 20% amplitude jitter. If it does not, adjust P6 on meter card so that multi-mode meter indicates 20% amplitude jitter.

3. Set 2A/2B AMPLITUDE MODULATION control to 50%. The multi-mode meter should indicate 50 ± 1% amplitude jitter.

4. Set 2A/2B AMPLITUDE MODULATION switch to OFF. The multi-mode meter should indicate less than 0.2% amplitude jitter.

b. If 2A/2B Line Simulator Is Not Available, the following procedure can be used. It is based on the fact that the in-phase component of single-frequency interference is amplitude jitter.

1. Depress OSCILLATOR OUTPUT FREQUENCY 1000Hz and METER MODE LEVEL buttons. Patch PB-1C-D OUTPUT to PB-1C-D INPUT. Set INPUT switch to 600Ω and HOLD COIL switch to OUT. Set OUTPUT LEVEL control for 0dBm indication on multi-mode meter.

2. Disconnect patch cord from PC-1C-D OUTPUT and plug into output of oscillator #1. Set oscillator #1 for 1200Hz on PB-1C-D frequency meter and −14dBm on multi-mode meter. (The in-phase component of −14dBm SFI is equivalent to 20% amplitude jitter).

3. Patch both PB-1C-D OUTPUT and oscillator **#**1 output to PB-1C-D INPUT, and set INPUT switch to BRIDGE. Oscillators will then terminate each other in 600 ohms. Depress PB-1C-D AMPL. JITTER switch. Multi-mode meter should indicate 20% amplitude jitter. If it does not, adjust P4 on meter card so that the multi-mode meter indicates 20% amplitude jitter.

4. Disconnect oscillator **#**1 and set PB-1C-D INPUT switch to 600Ω. The multi-mode meter should indicate less than 0.2% amplitude jitter.

5-17. PHASE JITTER Mode Adjustments (Meter Card)

a. If 2A/2B Line Simulator Is Available:

1. Set 2A/2B TONE FREQUENCY to 1000Hz, MODULATION FREQUENCY to 150Hz (modulation frequency range switch to X1), OUTPUT LEVEL to 0dBm, SOURCE IMPEDANCE to 600Ω, PHASE MODULATION switch to ON, all other 2A/2B toggle switches to OFF. Patch 2A/2B OUTPUT to PB-1C-D INPUT. Set PB-1C-D INPUT switch to 600Ω and HOLD COIL switch to OUT.

2. Depress PB-1C-D METER MODE PHASE JITTER button. Set 2A/2B PHASE MODULATION control to 20°. PB-1C-D multi-mode meter should indicate 20° phase jitter. If it does not, adjust P7 on meter card so that multi-mode meter indicates 20° phase jitter.

3. Set 2A/2B PHASE MODULATION control to 50°. The multi-mode meter should indicate 50 ± 1° phase jitter.

4. Set 2A/2B PHASE MODULATION switch to OFF. The multi-mode meter should indicate less than 0.2° phase jitter.

b. If 2A/2B Line Simulator Is Not Available, the following procedure can be used. It is based on the fact that the quadrature component of single-frequency interference is phase jitter.

1. Depress PB-1C-D OSCILLATOR OUTPUT FREQUENCY 1000Hz and MULTI-MODE METER LEVEL buttons. Patch PB-1C-D OUTPUT to PB-1C-D INPUT. Set INPUT switch to 600Ω and HOLD COIL switch to OUT. Set OUTPUT LEVEL control for 0dBm indication on multi-mode meter.

2. Disconnect patch cord from PB-1C-D OUTPUT and plug into output of oscillator **#**1. Set oscillator **#**1 for 1200Hz on PB-1C-D frequency meter and −15.2dBm on multi-mode meter. (The quadrature component of −15.2dBm SFI is equivalent to 20° phase jitter).

3. Patch both PC-1C-D OUTPUT and oscillator **#**1 output to PB-1C-D INPUT, and set INPUT switch to BRIDGE. Oscillators will then terminate each other in 600 ohms. Depress PB-1C-D AMPL. JITTER button. Multi-mode meter should indicate 20° phase jitter. If it does not, adjust P7 on meter card for 20° phase jitter indication.

4. Disconnect oscillator **#**1 and set PB-1C-D INPUT switch to 600Ω. The multi-mode meter should indicate less than 0.2° jitter.

5-18. Matching of Quasi-rms and Average Detectors. Patch the PB-1C-D OUTPUT jack to the INPUT jack and depress the OSCILLATOR OUTPUT FREQUENCY 1000+2000 button.

a. Depress the METER MODE LEVEL button and set the OUTPUT LEVEL for −30dBm on the multi-mode meter.

b. Depress the METER MODE NN SEP, REMOVE FILTER, CRT 2ND H, and SCALE MULT X5 buttons. The multi-mode meter should indicate −10dB. This is the level of the 2008Hz 'second harmonic' with respect to the 1004Hz 'fundamental'.

c. Depress METER MODE LEVEL, CRT 2ND H, SCALE MULT X5, and HARMONIC SEPARATION buttons and note the multi-mode meter indication. This is an **average** reading.

d. Depress METER MODE NN SEP, CRT MODE 2ND H, SCALE MULT X5, and HARMONIC SEPARATION buttons and note the multi-mode meter indication. This **quasi-rms** indication should be within ±0.2dB of the average indication in c. above. If it is not, set P9 on the dB card so that the quasi-rms indication is equal to the average indication of c. above.

e. Since the LEVEL mode employs average detection and the NOISE mode employs quasi-rms (peak plus average) detection, the procedure of matching the two detectors may change the correlation between LEVEL and NOISE modes which was established by the procedures of Par. 5-11. Therefore if it was necessary to alter the setting of P9 in the above procedure, repeat the procedures of Par. 5-11.

f. Depress CRT MODE 2ND H, SCALE MULT X5, and HARMONIC SEPARATION buttons, and set P14 on output card so that multi-mode meter indication is −10dB when METER MODE LEVEL, NOISE or NN SEP button is depressed.

Document Title: Product Manuals	Document Number: ESC-0305-92-01
Revision Number: A X B_ C_ D_ E_	Page: N/A
Prepared By: Rick Schultz	Approved By: [signature]
Issued By: Jim Steinau	Issue Date: 10/19/93

CHANGE NOTICE SUMMARY

Revision	Reason for Change	Date of Change

ACCOPRESS®

25970	YELLOW
25971	BLACK
25972	LIGHT BLUE
25973	DARK BLUE
25974	LIGHT GRAY
25975	LIGHT GREEN
25976	DARK GREEN
25977	TANGERINE
25978	RED
25979	EXECUTIVE RED

GENUINE PRESSBOARD

ACCO USA, INC.
770 S. ACCO PLAZA
WHEELING, IL 60090

www.manualsplus.com
1019511